MOBILE INTERACTION DESIGN APPROACHES FOR REDUCING DOMESTIC FOOD WASTE

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Abstract

Many commentators argue that domestic food waste is strongly influenced by consumer behaviours. These behaviours are promoted during food purchasing, consumption, and storage. A need exists to identify why people waste domestic food, which includes determining key factors that promote behaviours resulting in domestic food waste. The identification of these factors presents opportunities to use emerging technologies, such as ubiquitous computing, social computing, and mobile devices in order to reduce domestic food waste. Human-computer interaction (HCI) and interaction design (ID) are research areas that apply insights from behavioural psychology to inform design solutions. Specifically, HCI researchers have made inroads in overcoming the struggles associated with behaviour change, such as the challenge of maintaining a behaviour change over time. This study seeks to better understand how situated design interventions that build on fundamental HCI and ID concepts and principles present opportunities to tackle the problem of food waste from a different and novel perspective.

This thesis implements a transdisciplinary approach. It first examines why people waste domestic food by identifying key factors promoting behaviours that lead to domestic food waste. It then examines several situated design interventions that variously target the identified factors in order to encourage behaviour shifts towards reducing domestic food waste.

This thesis addresses the following two key research questions:

RQ1 – Why do people waste food at home?

RQ2 – How can situated design interventions encourage changes towards sustainable food practices within domestic environments?

The findings of this thesis identified three factors promoting behaviours leading to food waste:

1. **Supply knowledge** – does a consumer know what food they have available;

2. **Location knowledge** – does a consumer know where to locate food items, and;
3. **Food literacy** – to what degree do past experience and acquired knowledge impact on people's food consumption and disposal practices.

After investigating several design interventions, this study found that there are both positive and negative outcomes associated with interventions that target improved food supply, location, and literacy. It was determined that design, location, and features of interventions play a key part in the effectiveness of encouraging behaviour shifts and subsequently reducing food waste. Moreover, food location awareness is likely to reduce food waste more than providing food supply knowledge. However, improving both food supply and location awareness is likely to maintain behaviour changes over longer periods of time resulting in a reduction of domestic food waste. Interventions aiming to improve people's food literacy were also identified to be useful in encouraging people to utilise their food more efficiently and effectively. Food sharing was further identified as a useful mechanism to assist with reducing domestic food waste, particularly within a known community of sharers. However, this thesis also identified that sharing food or taking shared food within an unknown community of people is less desirable.

1. This study generated new and valuable knowledge for the academic and industry domains within the fields of HCI, urban informatics, environmental sustainability, food production, and public health.

This study is part of a larger ARC Linkage project entitled *Eat, Cook, Grow: Ubiquitous Technology for Sustainable Food Culture in the City:* www.urbaninformatics.net/food

Table of Contents

List of Publications

In accordance with §8.10 of the QUT PhD course regulations, this PhD thesis is being presented by published papers.

QUT permits the presentation of theses for the degree of Doctor of Philosophy (PhD) in the format of a minimum of three published and/or submitted papers, where at least one paper must be published, in press or accepted for publication by the time of the thesis lodgement for examination; and where the quality of such papers, and the student's contribution as author on those publications, has been assessed by the faculty as appropriate to PhD-level research.

The main body of this thesis is comprised of six publications:

4.1. Foth, M., Choi, J. H., Lyle, P., & Farr-Wharton, G. (2011, Aug 30 - Sep 2). Start playing with your food: Fun food experiences with mobile social media. In *Workshop Proceedings of Please Enjoy! Studying Playful Experiences with Mobile Technologies*, MobileHCI 2011, Stockholm, Sweden. http://eprints.qut.edu.au/43743/

4.2. Farr-Wharton, G., Foth, M., & Choi, J. H. (2014). Identifying Factors that Promote Consumer Behaviours Causing Expired Domestic Food Waste. *Journal of Consumer Behaviour* Vol 13, Issue 6, pages 393 – 402. http://eprints.qut.edu.au/70482/

5.1. Farr-Wharton, G., Foth, M., & Choi, J. H. (2012, Nov 26-30). Colour coding the fridge to reduce food waste. In *Proceedings of OZCHI 2012* (pp. 119-122), Melbourne, VIC. New York, NY: ACM. http://eprints.qut.edu.au/54184/

5.2. Farr-Wharton, G., Choi, J. H., & Foth, M. (2014, Nov 25-28). Technicolouring the Fridge: Reducing Food Waste through Uses of Colour-coding and Cameras. *Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia* (pp. 48-57), Melbourne, VIC: ACM. http://eprints.qut.edu.au/77532/

5.3. Farr-Wharton, G., Foth, M., & Choi, J. H. (2013, Sep 9). EatChaFood: Challenging technology design to slice food waste production. In *Green*

Food Technology: Ubicomp opportunities for reducing the environmental impacts of food, UbiComp Adjunct Proceedings (pp. 559-562), Zürich, Switzerland. New York, NY: ACM. http://eprints.qut.edu.au/60908/

5.4. Farr-Wharton, G., Choi, J. H., & Foth, M. (2014, Dec 2-5). Food Talks Back: Exploring the Role of Mobile Applications in Reducing Domestic Food Wastage. In *Proceedings of OZCHI 2014* (pp. 352-361), Sydney, NSW. New York, NY: ACM. http://eprints.qut.edu.au/75843/

The study also produced the following two related publications that were not included in the main body of the thesis:

a) Farr-Wharton, G., Lyle, P., Choi, J. H., & Foth, M. (2012). Health matters for subscribers to community-supported agriculture. *Food and Public Health*, *2*(6), 184-192. http://eprints.qut.edu.au/53174/

b) Choi, J. H., Foth, M., Farr-Wharton G., & Lyle, P. (2011, Sep 5-9). Designing for Engagement towards Healthier Lifestyles through Food Image Sharing: The Case of I8DAT. In *Proceedings of the Workshop on Promoting and Supporting Healthy Living by Design*, INTERACT 2011, Lisbon, Portugal. http://eprints.qut.edu.au/43739/

List of Figures

List of Tables

List of Abbreviations

Human-Computer Interaction (HCI)
Interaction Design (ID)
Convergent Interview Process (CIP)
Ethnographically Inspired Participant Observations (EIO)
Queensland University of Technology (QUT)
Theory of Planned Behaviour (TPB)
Transtheoretical Model (TTM)
Value-Belief-Norm Theory (VBN)

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Geremy Farr-Wharton

Signature: QUT Verified Signature

Date: ___March 2015_____

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Chapter 1: Introduction

This chapter provides an overview of this thesis to establish a shared understanding of the purpose of this research. It justifies the research, by outlining the research purpose: to identify key factors promoting those behaviours resulting in domestic food waste, and to investigate the role of ubiquitous technology, social computing, and mobile devices to facilitate shifts in consumer behaviours towards more sustainable food practices. Research questions and sub-research questions are presented to establish in readers a shared understanding of the individual components that each research question addresses and informs.

Secondly, an advanced summary of the literature review (Chapter 2) serves to illustrate the unfolding of the thesis: the motivation for this research, the problem this thesis addresses, the reason the problem exists, and a possible solution this thesis focuses on. A justification for this research is also presented, outlining where gaps in the literature are current. Current research gaps are identified, such as those regarding the identification of the key factors present during food purchasing, storage and consumption that promote those behaviours, which result in domestic food waste. The challenges faced when imbedding human-computer interaction (HCI) concepts and interaction design (ID) into interventions that target the impact of these factors to encourage behaviour change are also emphasised.

A summary is provided of the methodology and research design used to address the research questions. This thesis, grounded in HCI, pursues a user-centred design methodology that utilises a mixed methods approach to data collection and analysis. This thesis is aligned with a social constructivist framework and thus, an interpretive lens is applied to the research findings.

1.1 THESIS OVERVIEW

1.1.1 What is this thesis about?

Food waste is growing and remains an issue requiring the attention of multiple stakeholders (consumers, governments, industry) in the developed world. Evans, Campbell and Murcott (2013) and Evans (2011a) argue food waste is a recent concern that has emerged as a priority with regards to food policy and regulation, and

the environment. Currently, individuals spend a significant portion of their lives consuming food. However, individuals are unlikely to spend a similar amount of time contemplating the foods that are forgotten, partially consumed or left unconsumed, and that are subsequently discarded. The outcome of food waste has already had and will continue to have significant social, ecological, and economic implications if we do not take action to reduce its quantity, reduce its impact, or find alternative uses for it.

1.1.2 What is the issue?

Schneider (2008) argues that, on average, more than 25% of the global edible food supply is wasted every year, causing a potential threat to global food security. Food wastages occur along all phases of the supply chain. Significant portions of those wastages occur in domestic settings (Kantor, Lipton, Manchester, & Oliveira, 1997) and, in particular, originate from expired food. In Australia alone, households throw away nearly AU$6 billion worth of edible food each year (Hamilton, Denniss, & Baker, 2005); the figure is almost US$50 billion in the United States of America (Parfitt, Barthel, & Macnaughton, 2010) and £12 billion in the United Kingdom (Quested, Parry, Easteal and Swannell, 2011). Similar quantities of food are wasted in most developed nations, though some researchers identify food wastes to be even higher.

Schneider (2008) argues that food waste exists in one of four states: (i) the original food (unconsumed and expired food), (ii) leftovers (plate wastes), (iii) partly consumed or used food, and (iv) preparation residues (offcuts, fat from meat). The biological shells (e.g. vegetable and fruit peels, egg shells), the inedible biological elements of food (e.g. bones, coffee grounds) and the packaging of food are also considered food wastes (Schneider, 2008; Schneider & Obersteiner, 2007). Walker (2007) postulates that in some cultures food wastes are innovatively reused in a variety of novel ways, including traditional methods of cooking, animal feeds, and fertilisers. In their study of British mealtimes, Cappellini and Parsons (2013) discovered that families often try to explore how to reuse their leftovers and transform them into food for other mealtimes. Some waste is unavoidable: the biological shells and inedible biological elements of food. Original food, leftovers and partly consumed or used food products that expire and are subsequently discarded, do not necessarily reveal the waste of resources involved during food

production, processing, transportation, and disposal management. These are important factors to consider when exploring the impacts of wasting food, particularly because food wastes also demonstrate a waste of resources.

Discarded food, if not composted or incinerated, will often cumulate in landfill and undergo decomposition to produce a greenhouse gas known as methane gas (CH_4). Greenhouse gases, particularly methane, trap heat from the sun, causing a gradual compounding warming effect (often referred to as global warming). Wang, Odle III, Eleazer, and Bariaz (1997) estimate that amongst other contributors of global greenhouse gas, landfills produce 8% of total emissions each year. Wade (2011, p. 48) suggests that approximately 20% of the trash found in landfills is composed of food wastes. This signifies three inter-related challenges caused from food waste that impact the developed world: (i) environmental sustainability, (ii) exhausting landfill capacities, and (iii) jeopardising food security.

1.1.3 Why does the issue exist?

Domestic food wastes can be attributed to consumer behaviours and practices during food purchase, post-purchase, storage, preparation and consumption (Schneider & Obersteiner, 2007). Food is a deeply personal consideration for individuals; choices will often be reflective of complex social contexts and the cultural upbringing of the individual. An expanding gap in consumer knowledge, caused by a disconnect between food production and its consumption spanning the past 50 years (Mougeot, 1994), has led to a variety of problems in current global food systems. Heller and Keoleian (2000) suggest global food systems are not ecologically, socially or economically sustainable for a variety of reasons that have perpetuated over time. Main causes include the societal shift towards fast foods and ready-made meals (Green & Vergragt, 2002), centralised grocery outlets, availability of out-of-season and non-locally grown food, and increases in average food miles. Consumers will often reflect on food quality by its appearance, rather than its nutritional value (Green, Draper, & Dowler, 2003). Vidgen and Gallegos (2010) introduce their concept of food literacy to depict the competency for consumers to utilise food effectively. The concept refers to a consumer's knowledge of food and their understanding of how to use it to meet their needs. Misalignment in consumer knowledge and food literacy has led to the consumption of food that offers low nutritional value, increasing the potential of unhealthy eating habits (Ledikwe, Ello-

Martin, & Rolls, 2005; Wallace, 2007). The consumption of poor-quality foods (from, for example, fast food chains and instant meal packages) in developed nations has resulted in health related issues, such as obesity and diabetes, raising concerns about the existing food systems and the possible need to reform them (c.f. Hill & Peters, 1998; Ledikwe et al., 2005; L. R. Young & Nestle, 2002). In addition, Evans (2011b) argues that there is an interpretational issue underpinning waste generation, which has resulted in food policy and the general public assuming a misconception of a societal practice referred to as the 'throwaway society'. The misalignment in consumer knowledge has also led to consumer misconceptions of the terms 'use by,' 'best before,' and 'expired by,' promoting further ambiguity, since consumers may not understand the differences. These terms have different meanings regarding the edibility of food: 'use by' or 'expired by' indicate that food is recommended not to be consumed once it has past its expiry date; 'best before' indicates that a food can still be consumed after the expiration date has past, but may not be as fresh as it was originally intended to be. Relying on these dates means that consumers are less likely to use their own senses to judge food edibility, which is then reflected in their choice to either consume or discard food once it has passed its expiry (Caswell, 2008; Meah, 2013). This suggests that misconceptions in consumer knowledge and consumer behaviours can contribute and aggravate to domestic food waste. Further, Watson and Meah (2013) argue a divide exists to reduce domestic food waste. They suggest a growing number of campaigns and agencies target the reduction of food waste by encouraging socially and lawfully questionable activities such as 'food saving' and dumpster diving. However, while these endeavours aim to moralise such questionable methods of reducing waste, food security agencies place barriers and enforce policy to reduce the risk of food poisoning and other negative outcomes of consuming food considered 'wasted'.

The practice of storing food in domestic settings is a vital component in preventing waste consumption. However, very little research has targeted food storage to assist consumers in utilising food before expiry and in locating forgotten items. The variety of reasons why food storage may promote behaviours and practices that drive food waste need to be investigated and identified, to explore how to influence behaviours driving their domestic food wastage. Lebersorger (2008) and Schneider (2008) suggest an individual's appetite, desire for food, and the smell of

food are considerations that can influence a consumer's choice to consume or discard food. If a consumer chooses not to consume a food that was previously purchased for a specific mealtime, the food may consequently expire. Two-thirds of domestic food wastes are preventable if behaviours causing waste are targeted and influenced. Schneider (2008) suggests that preventative measures, embedded with consumer processes specifically aimed at reducing food wastes, must take a long-term perspective and a holistic approach. However, behaviours amongst individuals differ significantly and are therefore challenging to influence (Spangenberg & Lorek, 2002).

A number of factors contribute to the attitudes and perceptions of food and food waste that people develop over a lifetime. Quist, Szita Toth, and Green (1998) suggest several factors that can influence a person's behaviour towards food purchasing, eating, growing, cooking, waste management: the timing of meals eaten, the type of meals eaten, the consumption of ready-made packaged meals and unprepared food, how well a consumer is organised to take sufficient time for grocery shopping and cooking, how much food is purchased, and whether they grow their own food. In order to reduce the impact of these behaviours on food waste, new methods, approaches, and strategies of prevention must be explored.

1.1.4 How can the issue be fixed?

Prevention

In order to reduce domestic food waste, the factors promoting consumer behaviours causing food waste must first be identified. It is also important to identify preventative measures that can assist with reducing domestic food waste. Behaviours governing waste prevention can be determined by indicators such as an individual's age, income, and their time spent at home (Schneider & Obersteiner, 2007). Prevention starts with consumer food procurement (such as purchasing food at a grocery store). An individuals' attitudes, beliefs, and subjective practices are determinants of their shopping patterns (Robinson & Smith, 2002; Sikula & Costa, 1994; Vermeir & Verbeke, 2006). Calderon, Iglesias, Laca, Herrero, and Díaz (2010) suggest that individuals, particularly those with time-poor lifestyles, will actively seek more efficient methods of food purchasing and consumption. Chung and Myers Jr (1999) consider further aspects that can influence shopping patterns in consumers: an individual's disposable income, shopping convenience, number of people to be

shopped for, and time constraints. During the purchasing process, the price, quality and brand familiarity of food become key indicators of whether a consumer will choose to purchase or not to purchase an item (Carrigan & Attalla, 2001; Weatherell, Tregear, & Allinson, 2003). Evans (2012) argues prevention methods also include passing food down, around or otherwise saved from disposal.

Promoting and Encouraging Sustainable Behaviour

To reduce domestic food waste, consumer behaviours will need to change. Promoting and achieving a behaviour change may require a shift in focus away from attempting to directly target behaviours, instead targeting the underlying factors promoting those behaviours resulting in domestic food waste. Identifying and then impacting those factors may encourage more sustainable behaviours that would in turn reduce food waste. Maintaining behaviour change over time may also be achieved if the underlying factors currently causing unsustainable behaviours are influenced. Personal, social, cultural and environmental factors can influence an individual's behaviours and practices. Considering this, technologies that individuals regularly use in their everyday lives may have the potential to assist them with their interactions with food. Ubiquitous and social computing, and mobile devices are but some of the many areas that can be used to support reduced domestic food waste. The focus of this thesis explores this opportunity space to examine the role that technology can play in influencing the factors promoting behaviours that result in domestic food waste in order to assist individuals in adopting more sustainable behaviours in their everyday food practices.

Behaviour Change and HCI

Behaviour change has been a key focus area in recent HCI literature. For example, Fischer (2001) explores how HCI can provide methods for individuals to pursue environmentally sustainable lifestyles; Woodruff, Hasbrouck, and Augustin (2008) investigate the role of HCI in providing recognition of climate change. Individuals' motivation is a central focus of these studies, instigating such techniques as emotional and intrinsic motivation and gamification that implement goal setting and reward schemes. Success in achieving shifts towards desired behaviours in HCI studies has varied. Many studies that attempted to directly influence individuals' behaviours led to initial interest among the research participants, and often met with

changes in their behaviours. However, many fail to achieve long-term change in individuals' behaviours (Bishop, 2005).

The focus of this thesis is to identify significant factors that promote consumer behaviours resulting in excessive domestic food waste. In particular, the thesis examines the impact of specific interventions on the behaviours of individuals in relation to food waste habits. Blevis (2007) argues that HCI research targeting behaviour change should embed interaction and engagement into technology. Specifically, interventions may benefit from engaging individual users through incorporating features personally tailored to them. The environmental and external forces that could influence a user should also be considered. Brynjarsdottir et al. (2012) state a need for persuasive technology to be used in a behaviour change process. However, an individual's environment must be considered in the design process, because firstly, behaviours are different between individuals (Spangenberg & Lorek, 2002), and secondly, different contexts may stimulate different behaviours in individuals (Brynjarsdottir et al., 2012).

The contribution of this thesis is in filling a void in the literature by exploring the factors promoting consumer behaviours that result in domestic food waste. This thesis informs this gap by identifying the key factors promoting behaviours and then exploring several design interventions aimed at informing people's knowledge to reduce domestic food waste.

Benefits of Reducing Domestic Food Waste

Achieving a reduction in domestic food waste would see a decrease in land occupation required for landfill and a reduced production of greenhouse gas emissions from rotting food. The implications of this research are focused on the HCI discipline, in providing new concepts and design techniques appropriate for the context. However, the benefits extend to other domains such as consumer behaviour and food sustainability.

1.2 RESEARCH QUESTIONS

This study is grounded in the research field of HCI. The study explores ways to reduce domestic food waste by gaining rich insights into the interactions people have with their food and technology in domestic environments. Theories and methods of HCI and ID are then applied to interventions with the aim of influencing the

identified factors promoting the consumer behaviours that result in expired domestic waste. Schneider and Obersteiner (2007) suggest that two-thirds of domestic waste can be prevented by influencing an individual's behaviours. Blevis (2007) and Fogg (2002) indicate the effectiveness of technology in changing behavioural patterns and assisting individuals in their everyday lifestyles. Fogg (2002) and Froehlich (2009) further support the role that persuasive technologies can play in supporting individuals' adoption of more sustainable practices. Rather than attempting to directly influence an individual's behaviours, as has already been attempted in a variety of emerging HCI studies with limited success, this study targets the *factors promoting an individual's behaviours* that result in domestic food waste. To do this, the key factors promoting those behaviours that cause domestic food waste must first be identified. Once identified, design interventions can target the identified key factors in order to encourage more sustainable practices. Therefore, this thesis addresses the following two research questions:

RQ1 – Why do people waste food at home?

Non-composted domestic food waste intensifies global greenhouse gas emissions, constricts food security and delivers a significant sustainability predicament to the developed world (Schneider, 2008; Wang et al., 1997). Behaviours of everyday consumers are significant drivers of food waste; according to Schneider and Obersteiner (2007), two-thirds of domestic food waste can be prevented by impacting these behaviours. Achieving a shift in an individuals' behaviour is a complex task exacerbated by personal, social, cultural, and contextual forces. Even more challenging is the maintenance of changed behaviour over time (Bishop, 2005). To impact an individual's behaviour, key factors that promote behaviours causing domestic food waste must be identified.

RQ2 – How can situated design interventions encourage changes towards sustainable food practices within domestic environments?

Understanding how HCI and ID can be used to promote sustainable food purchasing, storage, and consumption practices in people is essential to this research. A behaviour change process may be stimulated if interventions leveraging these concepts can be used to influence the factors that promote behaviours resulting in food waste. A variety of initiatives can be undertaken to impact an individual's behaviours. Behaviour change has emerged as an interest area for recent HCI and ID

studies. This provides opportunity to explore the position of HCI in supporting a behaviour change process (Blevis, 2007; Fogg, 2002; Froehlich, 2009). To determine if HCI and ID can play a key role in assisting a decrease in domestic food waste by instigating a behaviour change process, this study evaluates a range of examples of domestically situated design interventions.

The two research questions illustrate the multi-dimensional problem-based research approach of this thesis. RQ1 focuses primarily on understanding human behaviours during food purchasing, storage, and consumption. This is to identify the causal factors promoting those behaviours that result in expired domestic food waste. RQ2 focuses on understanding how HCI and ID can influence the factors identified in RQ1, in order to influence the promoted behaviours to encourage sustainable food practices. Specifically, RQ2 explores how domestically situated interventions that build on HCI and ID can reduce food waste by facilitating food sharing and improving consumer food supply, location and level of food literacy.

1.3 CONTRIBUTION TO KNOWLEDGE

The research presented in this thesis uses knowledge, concepts and frameworks from three key research areas: HCI, food sustainability, and consumer behaviour. The literature review identifies in detail the gaps that currently exist in the literature and how those gaps will be informed by this thesis. There have been several studies identifying the key factors that influenced purchasing behaviours (c.f. Carrigan & Attalla, 2001; Chung & Myers Jr, 1999; Green & Vergragt, 2002; Quist et al., 1998; Spangenberg & Lorek, 2002; Weatherell et al., 2003), to my knowledge, there has been no study that has identified the significant factors influencing consumer behaviour that result in excess domestic food waste. This study informs these gaps.

Numerous studies carried out over the past few decades have researched food, behaviours and cultures, as well as HCI from disparate disciplinary perspectives, but few have used a transdisciplinary approach. A transdisciplinary approach focuses "on goals that emerge from a focus on values, issues, as well as ontological and epistemological perspectives, appealing to disciplinary notions of method and domains of expertise as needed and in the service of these larger goals" (Choi & Blevis, 2010, p. 113). An interpretive lens applied to my research was aligned within a social constructivist framework. This approach was chosen to provide the most

appropriate understanding of two main aspects, (i) the factors promoting those behaviours resulting in domestic food waste, and (ii) the role of domestically situated interventions to facilitate food sharing and improve consumer food supply, location and literacy to reduce food waste. These new insights from my study provide consumers with mechanisms to support sustainable food practices and reduce domestic food waste. This study acknowledges the disciplinary divides and emphasises the need for transdisciplinarity (Choi & Blevis, 2010; Max-Neef, 2005, p. 7), which enables key models and ideas from these areas to form new relationships between the disciplines and in turn provide an opportunity to reduce food waste in households. The theoretical outcome of this research is the identification of the significant factors that influence consumer behaviour that result in domestic food waste (particularly expired food waste). In turn, this leads to the identification of specific design opportunities for HCI to engage consumers by providing them with mechanisms to support knowledge and awareness about their food purchasing, storage, and consumption practices. Improving people's of their food purchasing, storage and consumption practices may provide them with the opportunity to reduce food stockpiling and may increase the visibility of otherwise often forgotten foods. An evaluation of HCI and the role it can play in the process of indirectly facilitating a shift in individuals' behaviours is undertaken and the insights can be used in other situations that target similar outcomes. In particular, the interventions undertaken target tailored information and design elements that are aimed at raising individuals' awareness about their food purchasing, storage and consumption practices in order to improve consumer food supply, location and literacy.

More recently, studies have been aimed at the implementation of HCI design principles to influence behavioural change (especially within the domain of climate change). There have been some successes with these studies, where key design attributes have been identified that encourage a change in behavioural and habitual patterns in those attributes that help to maintain change over time (c.f. Bishop, 2005; Creed, 2006; Dillahunt, Becker, Mankoff, & Kraut, 2008). However, Jackson (2005) argues that directly changing behaviour towards more sustainable practices is often quite difficult to achieve requiring a significant amount of time and maintenance. For this reason, this study aims to instigate a change in the factors that promote behaviours resulting in domestic food wastage, rather than attempting to change

behaviours directly, as this would encourage a change towards sustainable food practices as a protracted routine.

This thesis then contributes new and valuable knowledge for academic and industry domains within the fields of HCI, urban informatics, environmental sustainability, consumer behaviour, and food sustainability.

1.4 THESIS STRUCTURE

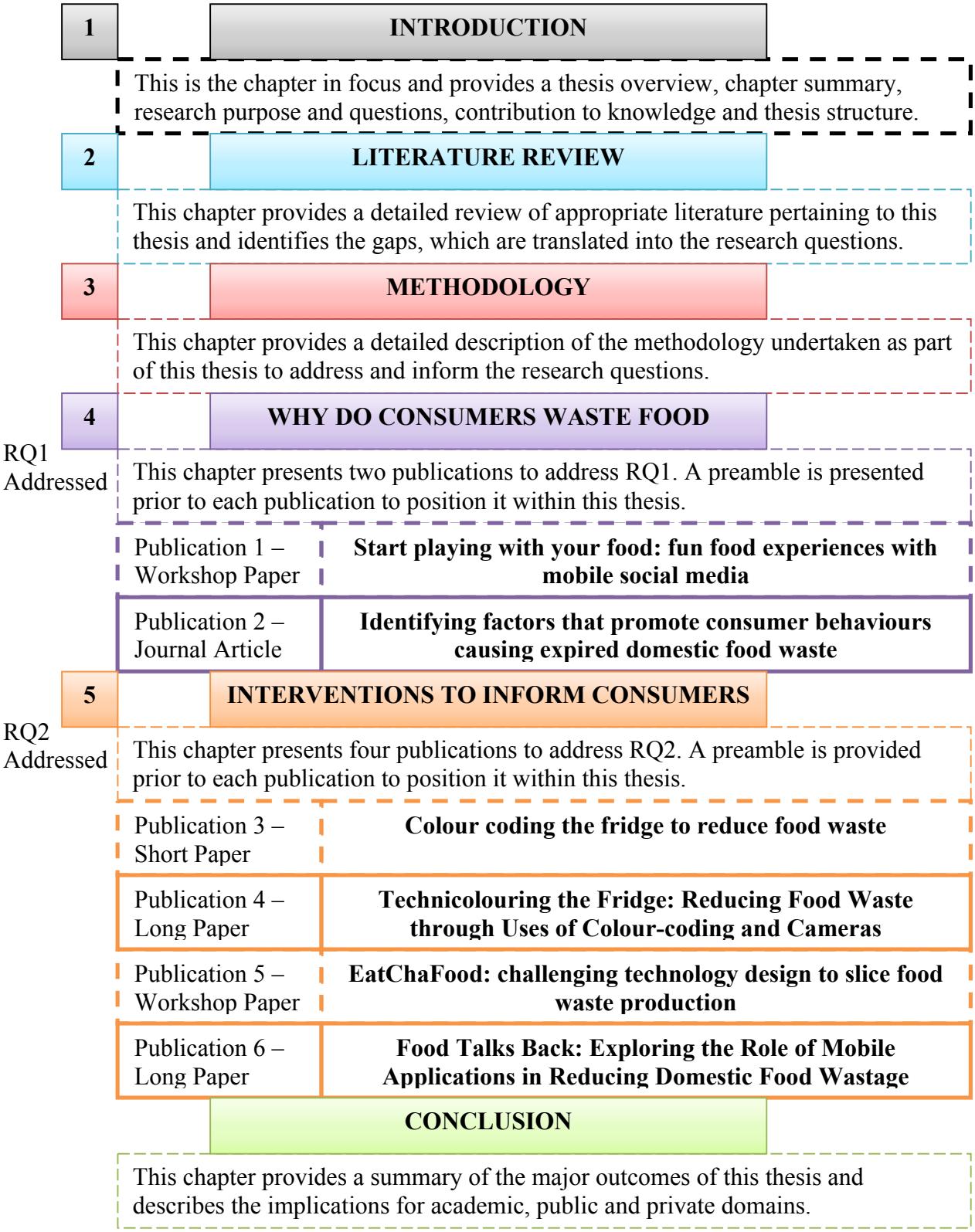


Figure - 1 A visual representation of the structure this thesis follows.

1.5 SUMMARY OF CHAPTER ONE

The object of this chapter was to provide an overview of this thesis, including a statement of the research purpose and research questions, an outline of the literature review, a brief description of the methodology, and the structure map of this thesis. Through presenting this information, I have sought to provide a shared understanding of why this research is needed, what research questions this thesis addresses, and how the research is addressed.

Chapter 2: Literature Review

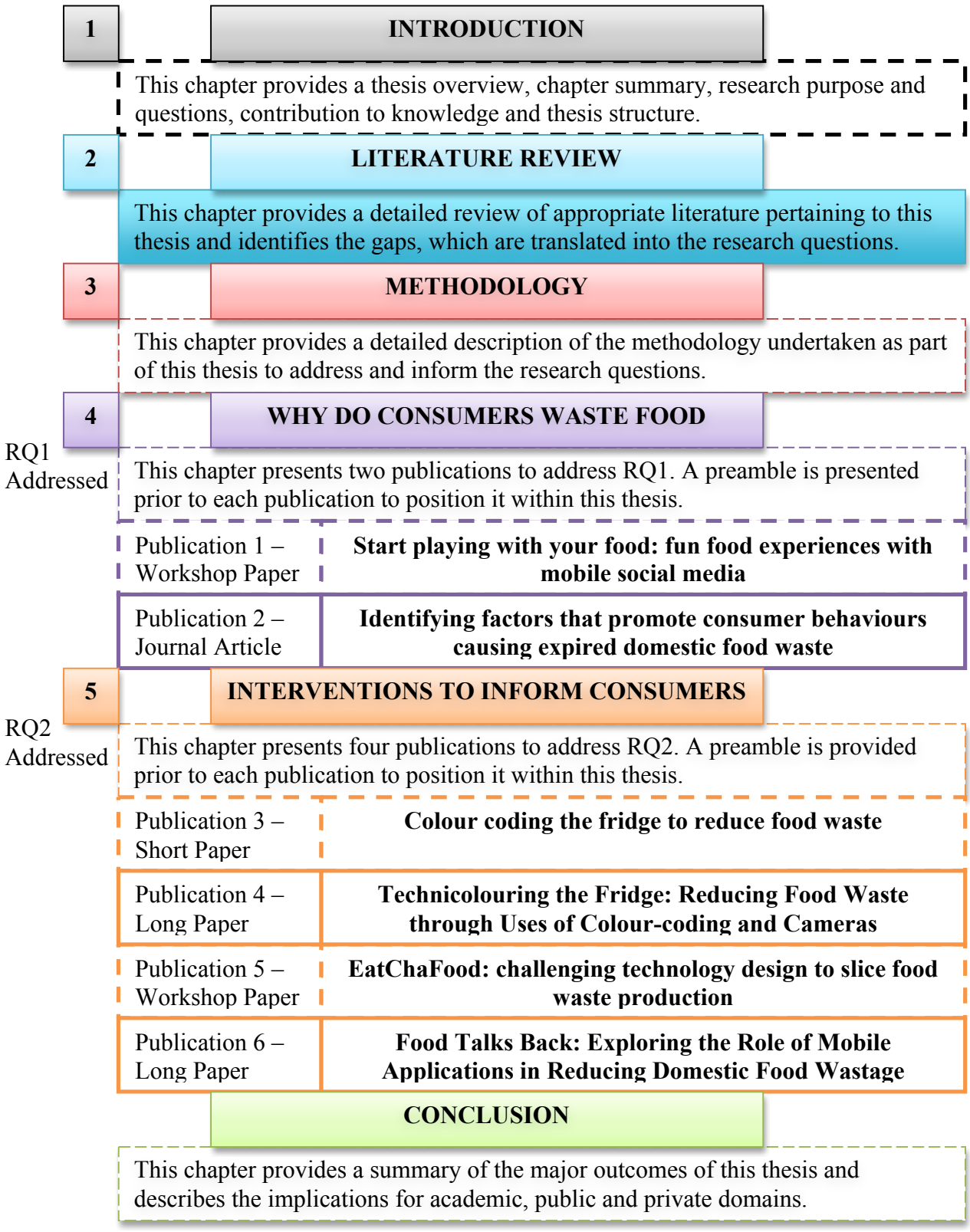


Figure - 2 A visual representation of the thesis structure with a focus on the current Chapter.

This chapter presents a review of literature relevant to this thesis. It begins by detailing the initial motivations for the research. In particular, the first section identifies **food waste** as the focal point of this thesis: the impacts of food waste on different areas of society, with a specific focus on domestic food waste, and the causes associated with food waste in domestic settings. The second section explores literature pertaining to **consumer behaviour** and behavioural change, with a focus on how behaviours can influence food waste. In light of the literature raised, an argument is put forward, suggesting there are contributing factors that promote and encourage behaviours resulting in domestic food waste that are yet to be explored. This argument is translated into RQ1 (Ch. 1, Section 1.2, pg. 7).

The third section explores the literature in **ID** and **HCI** regarding the use of technology to encourage behaviour change. This is used to describe key insights from industry and academia about effective design dimensions that may be integrated into technology so as to encourage behavioural change in its users. In particular, a review of literature identifies available technologies that can be used to promote changes towards more sustainable food practices. This leads to the second research question RQ2 (Ch. 1, Section 1.2, pg. 8).

2.1 FOOD WASTE

2.1.1 The Endemic Nature of Wasting Food

Decreasing food waste is a global concern that has gained attention in recent years. Food waste has a variety of effects that directly and indirectly effects different areas of society, such as the economy, environment, food security, and land availability (Gustavsson, Cederberg, Sonesson & Emanuelsson, 2013; Halloran, Clement, Kornum, Bucatariu and Magid, 2014; Kaiser, 2011; Quested, Marsh, Stunell & Parry, 2013). The majority of food, once wasted, will likely enter the municipal waste stream and end its lifecycle in landfill. Once in landfill, food decomposes releasing methane gas into the atmosphere, which contributes to global greenhouse gas emissions. Wang et al. (1997) argue that landfill decomposition gases add approximately 8% to total global greenhouse gas emissions each year. This contributes to the global warming effect and increases the need for land estates to house exhausted landfill capacities. Further, wasted foods also represents a waste of resources used in the production, processing, marketing, transport, and refrigeration

of food (cf. Fischer, Frohberg, Parry, Rosenzweig, & Downing, 1995; Godfray et al., 2010; Parfitt et al., 2010; Parry, Rosenzweig, Iglesias, Livermore, & Fischer, 2004; Rosenzweig & Parry, 1994).

Combating issues regarding wasted resources is paramount, because the earth is reaching a point where it is unable to sustain the quantities of resources taken out of the ground for use in goods and services (Bekken & Marie, 2007). Recently, attention has been given to the different phenomena impacting the environment in light of a greater prevalence and severity of natural disasters associated with shifts in the global climate. As nations across the globe continue to develop and prosper, equilibrium between the resources we mine and use and the impact this usage has on the environment is essential for a sustained future. The most recent report by the Intergovernmental Panel on Climate Change states that global food security is under threat (IPCC, 2013). A variety of considerations have been investigated in leading to this conclusion, such as a shifting climate causing extreme flood and drought situations, impacting the ability to grow seasonal crops, and thereby impacting global food production. Therefore, the threat of shifting climates presents a risk to the future of food security if the facets of food processing, storage, consumption and waste processing are not managed more efficiently. Specifically, the situation also poses a risk to sustainable food growing, access, nutrition, and distribution (Lawrence, Lyons, & Wallington, 2009, 2010; S. Maxwell & Smith, 1992). Food security refers to the ability for a nation to feed its population from its available edible food supply. Further, food security became a growing concern when access to food supplies became threatened for a variety of reasons, but particularly because of a dwindling nutritional food supply (S. Maxwell & Smith, 1992). The changing climate also presents a risk to environmental sustainability and wasted resources, because of the two climate extremes that are becoming more prevalent: drought and major inundation caused from flooding. This situation encourages more efficient utilisation of our current food systems to reduce wastage. Previous research has sought to raise awareness of the ecological, social, economical, and health related implications of wasting food within society by providing communities with information relating to the impact (c.f. Griffin, Sobal, & Lyson, 2009; Kantor et al., 1997; Parfitt et al., 2010). However, Heller and Keoleian (2000) argue that many food systems are not ecologically, economically, or socially sustainable, and this must be addressed in the

near future. Reducing food waste and thereby reducing the impact of food waste first requires identifying where wastages occur.

2.1.2 Impact of Wasting Food

Food losses occur when food grown for distribution as a commodity or sale to everyday consumers fails to meet key processing and selling requirements and is subsequently discarded. Food losses occur at each stage of the food supply chain; not all food grown is selected for edible consumption and therefore, dissemination through food retail outlets and grocery stores. During processing, food that is bruised or contains blemishes is often rejected for sale, because consumers often have a belief that blemishes or bruising are signs of spoilt or tainted food (Green et al., 2003). Therefore, saleability is reduced. Many of these foods are still edible, but are either disposed of as municipal waste, or other methods to utilise the food losses are employed, such as livestock feeds, fertilisers, and traditional methods of cooking (Walker, 2007). The reason for this may stem from a lack of consumer understanding about food and its origins, caused from consumer knowledge disparity between food's production and its consumption. This has developed over the past three decades in industrialised nations (Mougeot, 1994). This has meant that in some cases, consumers misunderstand that food is grown and processed before entering outlets such as grocery stores, and this misconception is intensifying the longer it goes unaddressed. Various public and private initiatives have invested in a number of campaigns, policies and procedures that target reduced volumes of food wastes during crucial stages of the food supply chain. Several initiatives have focused on alterations to food management by the agricultural, processing, hospitality, and food retail industries (c.f. Kantor et al., 1997; Parfitt et al., 2010). Further initiatives have targeted the marketing commerce of food retail grocers, such as marketing ploys designed to encourage consumers to purchase items close to expiry to reduce food spoilage (Tsiros & Heilman, 2005). These studies further examined consumer behaviour to inform food policies and industry standards. These studies also demonstrate that wastages occurring during the production, procurement, processing, and dissemination stages of the food supply chain are being addressed in various ways. However, domestic settings are an under-addressed area where wastages are most prevalent. This study will specifically focus on this area.

Ambler-Edwards et al. (2009) argue that the majority of food wastes occurs in domestic settings and to a lesser extent, as Kantor et al. (1997) suggest, in food retail outlets. To reinforce this, Caswell (2008) determines that the average consumers' annual household garbage will comprise between 40% and 60% food waste in the UK. Once household garbage is collected, it is commonly deposited in landfill, and Wade (2011, p. 48) suggests Australian household waste accounts for approximately 20% of landfill capacities. Further, in US households, Kantor et al. (1997) identified that portions of household waste comprised food that was forgotten and had expired in storage. Schneider and Obersteiner (2007) identified that preparation residues and leftover foods were contributing 30% and 18% respectively to overall household food waste in Europe. For this reason, Schneider and Obersteiner (2007) argue two-thirds of domestic food wastes are preventable. This presents the initial motivations for this study to target reduced domestic food waste and is subsequently supported in contrast to 25% of the annual global edible food supply being wasted (Schneider, 2008). To put this figure into perspective, Wenlock, Buss, Derry, and Dixon (2008) argued that wasted food comprised approximately 4% of the total household garbage in the 1980s. The percentage of wasted food in household garbage had consequently risen to 22% in 2008, and even higher at 25% in 2012 (Gunders, 2012). Overall, more food is being wasted.

However, in order to measure quantities of wasted food, food waste and what it comprises must first be identified. Schneider (2008) argues food wastes can be identified in one of four wasted states: (i) the original consumable food, (ii) a partly consumed or used food, (iii) leftovers, such as plate waste or unconsumed edible food used in meal preparation, (iv) inedible preparation residues, such as meat offcuts and fat, egg shells, coffee grounds, bones and peelings from fruit and vegetables. Some of these wastes are inevitable outcomes of consuming food. For example, inedible preparation residues are the outcome of consuming a specific product, such as eggs or coffee, which leave eggshells and coffee grounds as by-products. However, the remaining states of food waste, such as the original food, partly consumed or used food, and leftovers, are preventable (Schneider & Obersteiner, 2007). This presents an opportunity to explore design interventions as a way of assisting in their prevention.

2.1.3 Behaviours Governing Domestic Food Waste

A number of considerations can result in food being wasted. Consumer behaviours are one such consideration. Significant quantities of domestic food wastes are attributable to consumer behaviours. These behaviours are promoted by various influences occurring during the process of food purchasing, storage, cooking and consumption. In addition, incorrect and misinformed knowledge can drive particular behaviours that result in food waste, such as the ambiguity regarding consumer understanding of expiration dates (e.g. 'use by' and 'best before'). For example, Green et al. (2003) indicate that food quality, sustenance and nutritional value are measured by food's appearance, which is often associating bruised and blemished products with tainted food. In their study of Australian consumers, Dixon and Isaacs (2012) discovered a discrepancy between desire and actual behaviour of consumers. They identified that consumers are able to associate the nutritional value of food with how fresh it is. However, consumers are more likely to purchase process foods that are cheaper, create less waste and are preferred by their children. Further, a variety of different conditions of a person's lifestyle can also impact on conditions that promote behaviours resulting in domestic food waste (cf. Schlegelmilch, Bohlen, & Diamantopoulos, 1996; W. Young, Hwang, McDonald, & Oates, 2010). This can promote apathetic consumer purchasing behaviours, which are reflected in bulk purchases, because the products are often cheaper than buying the same quantity of the single product. However, particularly with produce, it is not always practical to consume the bulk amount purchased within the time between purchase and expiry. The excess unused food will likely expire and be discarded as a result, without having been consumed (Godfray et al., 2010). There may also be little regard for the wasted resources that have gone into the production, processing, transportation, and refrigeration of the discarded excess unused food

Discarding food is a common practice once food reaches its expiry. It is then subsequently replaced with a fresher product. In recent decades, this has generally become a comfortable practice for people in the developed world that has continued because of the overproduction of food. Food overproduction is a major contributor to global food waste (Darlington & Rahimifard, 2006; Darlington, Staikos, & Rahimifard, 2009). Overproduction in the developed world is met with marketing ploys utilised by centralised food distributors and is passed on to consumers through

several different marketing techniques (Vermeir & Verbeke, 2006). For example, marketing ploys encourage consumers to purchase food in bulk to save on the cost of buying a similar quantity of the single product. This encourages consumers to purchase food in large quantities, because it is cheaper to do so (Kader, 2004). Often a quantity of food remains unconsumed before reaching expiry and is in turn discarded. Furthermore, 'specials' are another marketing technique utilised to encourage consumers to purchase items they may not need. Baumeister (2002) and Ene (2008) both argue that consumers are encouraged to purchase food excessively, because they are exposed to marketing ploys that influence their decisions to buy products impulsively, irrespective of the value to consumers. This can also encourage purchases of food already in a consumer's food storage. In either case, consumer stockpiling can occur, which increases the risk of foods being forgotten (Kantor et al., 1997) and subsequently expiring as a result. This highlights a lack of awareness about which foods are available at home when shopping for groceries.

Jager (2000) offers a consumer purchasing behaviour model which can be used as a mechanism to predict and understand consumer purchasing behaviours. The model depicts three determinants of behaviour intention for an individual in a given situation, and consumer action is dependent on both attitude and behaviour. Vermeir and Verbeke (2006) extended the Jager (2000) model to include a mechanism that explained how attitude would be affected by other factors, such as (i) involvement and values of consumers, (ii) consumers (un)certainty surrounding information and knowledge of products and how they link to sustainability, and (iii) behavioural control that is demonstrated in perceived availability of products and perceived consumer effectiveness.

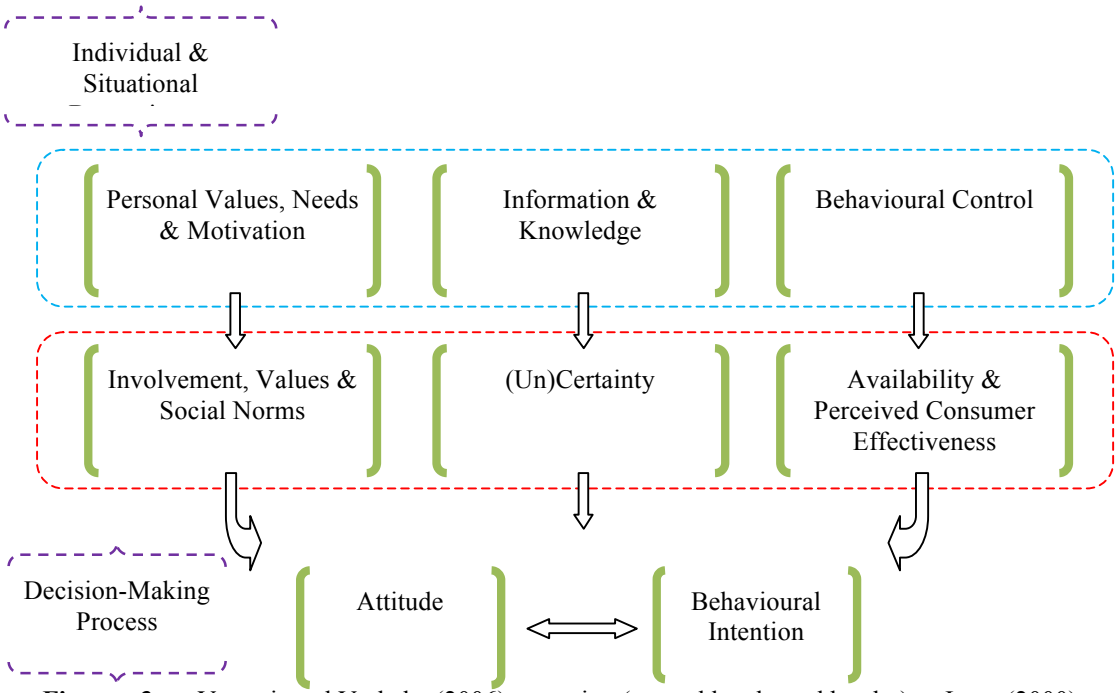


Figure - 3 Vermeir and Verbeke (2006) extension (second level – red border) to Jager (2000) original consumer purchasing behaviour model (top level – blue border).

The extended model presents an opportunity to understand consumer purchasing patterns. However, a key limitation of the model is that it does not describe the process under which a consumer will undertake a transition to sustainable purchasing patterns or to what combination of factors can assist the decision-making process to help a consumer achieve sustainable purchasing patterns. Alternatively, the model can be used to inform a better understanding of consumer decision-making during food purchasing. In their review, Tsiros and Heilman (2005) explored methods for industry to assist with reduced food spoilage by examining consumer behaviours regarding the effect that expiration dates have on purchasing decisions. Their insights show that many consumers require a greater awareness of food expiry labelling and the literacy to adequately interpret such labels. This would enable consumers to become better informed about accidental product purchases that are close to expiry. Tsiros and Heilman (2005) also argue that there is a greater need for industry to provide uniform classification methods to date the expiry of food. This action would serve to further reduce consumer confusion with regards to food expiration, not only during food purchasing, but in domestic settings as well. These external influences point to underlying factors that promote particular food purchasing behaviours that contribute to domestic food waste, such as the stockpiling of food. To help overcome these influences, this study investigates the factors promoting those behaviours that result in domestic food waste. Understanding the

circumstances that promote consumer behaviours resulting in wasted food presents the opportunity to explore ways of mitigating the impact of those circumstances, thereby potentially reducing domestic food wastes.

2.1.4 Reducing Domestic Food Waste

Factors that influence food behaviours include social norms, attitudes, cultural upbringing, and the experience, knowledge, and understanding of food (Brunner, Geyer, Jelenko, Weiss, & Astleithner, 2007, cited in Ganglbauer, Fitzpatrick, & Comber, 2013). Knowledge and understanding of food refer to an individual's *food literacy* (Vidgen & Gallegos, 2010). Vidgen and Gallegos (2010) describe food literacy as the knowledge and understanding that individuals and communities have of food, and how it can be used to meet their needs.

Schneider and Obersteiner (2007) provide key drivers that shape behaviours, resulting in food wastage. They suggest that age, income, and time spent at home are factors to consider when examining behaviours. Situational conditions, such as smell, appetite, and desire for food, have implications for food wastage (Schneider, 2008). Further, behaviours are conditioned by a consumer's sociocultural, experiential, symbolic, and ideological nature (Arnould & Thompson, 2005). Schneider (2008) proposes several methods of waste prevention for use in households: a shopping list, using highlighted tabulated measurements for rational food portion sizes, education in creative uses of food leftovers, education about the equivalent monetary value of wasted food items for a given consumer, and general food waste awareness training. The majority of these methods target the need to improve food literacy amongst consumers, heightening awareness of those practices prone to producing wastage, and offering methods to reduce waste. Therefore, the literature gap that this thesis addresses is: *Why do people waste food at home? (RQ1)*. However, identifying the key causes of food waste is only part of the problem. Once the causes have been identified, steps can be taken to influence the causes and thereby encourage a change in people's behaviour.

2.2 BEHAVIOUR CHANGE

Past interventions that have sought to influence consumer behaviours have been met with immense challenges and, consequently, have had varying levels of successes. Hadfield-Hill (2012) found that there are various obstructions to

encouraging and maintaining pro-environment behaviours that must be overcome. Vermeir and Verbekev (2006) argue that increases in consumer interest and attitudes towards sustainable food practices do not necessarily trigger a change in consumer behaviour. This translates to the fact that while consumers may have an interest in sustainable food practices, external factors may prevent them from performing and sustaining such practices. Stern (2000) argues the most effective approach to encourage a change in environmentally significant behaviour requires a combination of interventions targeting factors that impact on individuals: (i) using religious and moral approaches that appeal to the values of individuals and influence their worldviews, (ii) providing information and education to shift an individuals' attitude, (iii) rewarding desired behaviours through material or monetary incentives and penalising individuals for undesired, (iv) providing a shared understanding of rules and expectations through community management. However, Stern (2000) also argues that, regardless of the combination of interventions used, at least one intervention must target the removal of key barriers preventing a change process to occur and should be tailored to an individual's situation to ensure the most comfortable transition into changed behaviour assimilation.

Meulenberg (2003) suggests sustainable food practices are based on a decision-making process that engages a consumer, not only in their individual desires and needs, but also in their perceived social responsibility. This suggests that consumers feel a social responsibility and pressure to make decisions based on their perception of sustainable food practices. Further, Vermeir and Verbekev (2006) argue that everyday purchasing and consumption practices are heavily motivated by a variety of situational influences such as convenience, habitual behaviour, diet and health concerns, perceived value for money, hedonism / lifestyle, and social responsibility perceived through social norms. However, even when these influences meet with consumer comfort, some consumers are still resistant to change (Dawson, 2000; Tucker & Douglas, 2007). This emphasises the challenges of targeting behaviour change directly and reinforces the need to consider opportunities to influence external factors, to encourage more sustainable behaviours resulting in reduced domestic food waste.

2.2.1 Comparison of Behaviour Change Theories

There are a number of different theoretical paradigms and research methods about behaviour change. The Theory of Planned Behaviour (TPB) is widely used to explain behaviour change by providing possible causes of behaviour through examining consumers' beliefs, attitudes, and intentions (Ajzen, 2011). However, the TPB fails to incorporate a number of indicators, which Stern (2000) argues are essential to understanding the causes of environmentally significant behaviours. Firstly, the TPB does not accommodate for a consumer's knowledge and skill required for particular actions and is therefore inadequate for determining the impact of such indicators. Secondly, a number of external influences are not included in the TPB formula, such as community expectations, advertisement and marketing, and public policies in place to support behaviour. Stern (2000) further argued that theories, which only examine intent, provide an insufficient understanding of how to change environmentally significant behaviours.

The Transtheoretical Model (TTM) developed by Prochaska, Norcross, and DiClemente (1995) has been extensively used to determine the likelihood of an individual to progress through steps of behaviour change and to provide mechanisms to support and maintain changed behaviours (He, Greenberg, & Huang, 2010). The TTM is a psychological theory that has been used to predict health related behaviour change. However, limited adoption of the model has been undertaken to predict behaviour change regarding environmentally significant behaviours (Nisbet & Gick, 2008). Further, the TTM provides a mechanism to assist in changing behaviours – once the causes of behaviour have been identified – but not a mechanism to identify the causes of behaviour themselves.

The value-belief-norm (VBN) theory provides a framework in which to examine the causes of behaviours that are associated with non-activist environmentalism, which refers to consumers whose behaviours impact the environment, regardless of intent (Stern, 2000). Therefore, the VBN theory has proven useful in this thesis for examining the impact of consumer decision-making behaviour regarding food and its associated waste. Understanding the circumstances in which these behaviours occur helps to identify the original causes. These causes can then be addressed to encourage a change in behaviour (Stern, 2000). Stern (2000)

argues that behaviours associated with non-activist environmentalism are caused from four types of considerations:

- *Attitudinal factors regarding an individual's norms, values and beliefs;*
- *External or contextual forces, that is, the level of impact that community, institutional, social and legal expectations have on an individual;*
- *Personal capabilities concerning the knowledge and skills required for an individual to perform an action;*
- *Habit or routine regarding an individual's established habitual behaviour and everyday practice.*

Different combinations of these conditions can influence an individual's behaviour. For this reason, the VBN theory is identified to be the most adequate theoretical framework to analyse the data collected as part of this thesis, to reveal why consumers waste domestic food.

2.3 HUMAN-COMPUTER INTERACTION

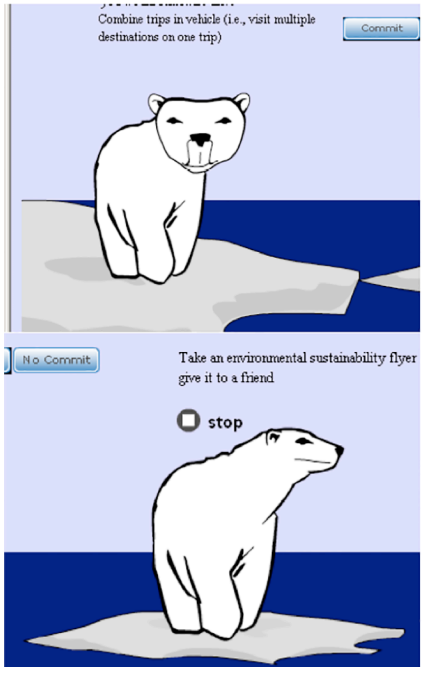
2.3.1 Encouraging Behaviour Change through Technology

Using technology and HCI concepts to encourage sustainable behaviours is only one of many ways to reduce domestic food waste. However, in recent years, emerging HCI studies have provided some opportunities to better enable both the recognition of climate change (Woodruff et al., 2008) and methods for providing a more sustainable lifestyle both for the individual and for society (Fischer, 2001). Evidence has shown that individuals, when given the choice, predominately prefer an environmentally friendly option (Autio & Wilska, 2005). This is an important consideration with respect to the impact of wasted food on the environment. It is reasonable to assume that consumers would prefer food was consumed or used, rather than wasted.

In addition, Blevis (2007) and Fogg (2002) position HCI as a key area of practice to assist a behaviour change process. Previous studies have explored the effectiveness of several motivational techniques such as rewards, emotional motivation, intrinsic motivation, gamification, and goal setting. However, maintaining changed behaviours over time has proven difficult (Bishop, 2005). This

is often due to the novelty effect: individuals experience an initial interest and motivation to change behaviour, but over time, the interest dissipates because of lifestyle, time availability and other external factors (Jackson, 2005). Further, Blevis (2007) argued that HCI research must consider embedding interaction and engagement into technology to stimulate a behaviour change process. This consideration has been approached using four complementary mandates:

- *Provide people with knowledge and awareness of their consumption practices as to encourage a change towards more sustainable practices (Dillahunt et al., 2008).*
- *Target the integration of persuasive techniques and methods into technology to assist individuals to adopt sustainable practices with tasks and activities undertaken in their everyday life (Hutchinson, 2007; Wakkary & Tanenbaum, 2009).*
- *Use an approach that combines the preceding two perspectives in order to instigate a change towards more sustainable consumer practices.*
- *Aim to change the environments we live in through an activist approach (Busse et al., 2013; Ganglbauer, Fitzpatrick, & Comber, 2013). The successes and failures of HCI behaviour change studies have varied, with many studies gaining initial interest and stimulating behaviour changes, but failing to maintain those behaviours over time. An example is the polar bear experiment (Dillahunt et al., 2008). The virtual polar bear[1] was used to motivate users into decreasing energy consumption and increasing sustainable practices. It encouraged reduced energy consumption by engaging a user's emotions and changing the state of the bear depending on energy consumption. The bear would appear happy and playful when consumption was low and sad*



[1] Image to the right retrieved from Dillahunt et al. (2008).

when consumption was high. Dillahunt et al. (2008) documented the challenges of maintaining behaviour change. Participants gave feedback, stating that over time they would turn the bear off or ignore its reaction to energy consumption. A reason given indicates it was repetitive and often participants did not feel as though they could do anything about their energy consumption, which had impact on the bear.

Each of these approaches requires further investigation to determine the most appropriate ways in which the design of technology, building on HCI, can encourage and maintain changed behaviour. Moreover, these approaches provide justification for this study's investigation into situated interventions that build on HCI concepts to target the key factors promoting those consumer behaviours that result in domestic food waste. Such interventions may provide a seamless and comfortable transition towards more sustainable behaviour patterns and may assist in the maintenance of those behaviour patterns in the longer term.

Further, a number of interventions have targeted domestic settings, specifically aiming to provide support for people to undertake tasks associated with their everyday lives. An example is the Internet Fridge (also known as the Smart Fridge). The aim of numerous iterations of the Internet Fridge was to provide Internet and multimedia access to benefit users. This was facilitated through a visual display located on the front of the fridge door. The display provided a number of features that enabled users to (i) browse the Internet, (ii) manage household appliances remotely, such as air conditioners, and (iii) manage a limited range of their food supply stocks through sensory information to automatically re-order food items and thereby reduce the shopping burden of users (Chi, Chen, Liu, & Chu, 2007). The Internet Fridge is an example of a technology that has failed to saturate the market. There were various reasons for its downfall, but it is widely accepted that the technology's benefits were ambiguous to users, particularly when compared to the benefits of the common household refrigerator (Halupka, 2012; Lueg, 2002). The high costs associated with purchasing the Internet Fridge further deterred people from adopting the technology and contributed to the perception of an unnecessary commodity. This outcome provides opportunities to investigate interventions that may help overcome the shortcomings of innovations such as the Internet Fridge, and thereby provide increased benefits to users.

These sets of literature provide insights into the different perspectives that may influence the design of an intervention. It further highlights a gap in the research, which is informed by this thesis: *How can situated design interventions encourage changes towards sustainable food practices within domestic environments? (RQ2)*

2.3.2 Mobile and Ubiquitous Interventions to Reduce Food Waste

Industry has a variety of policies and initiatives in place to reduce and manage food waste, such as using waste as animal feed (Darlington et al., 2009; Tsiros & Heilman, 2005). However, domestic food waste is largely uncontrolled despite numerous public and private attempts to reduce it by implementing such methods as raising food waste awareness, behavioural modification and persuasion using intrinsic and incentive motivation (e.g. Bucci, Calefato, Colombetti, Milani, & Montanari, 2010; Thieme et al., 2012). Example studies of interventions targeting these methods are Bucci et al. (2010) and Thieme et al. (2012). Bucci et al. (2010) examined a fridge that alerts users about product expiration dates, suggests recipes, sends shopping lists via SMS or email, and posts messages to household members. Thieme et al. (2012) examined the effectiveness of BinCam, a camera placed in a bin alerting consumers of their waste practices (Figure 4). In many cases, these and similar interventions failed to meet expectations of behavioural change. A range of explanations why these initiatives failed to result in sustained behaviour change include aspects such as a person's perceived usefulness, perceived ease of use (Davis, 1986), and challenges regarding consumers' acceptance to use technology aimed at supporting everyday activities and practices. However, recent innovations in mobile application development have provided some new avenues for optimism to encourage food waste reduction.

Figure - 4 A photo of BinCam[2].

Another solution to assist with reducing food waste is food sharing. Sharing food is not a new practice. Food bank types of establishments operate by sharing food to those who need it, rather than allowing it to be wasted. Some establishments also provide further benefits to their members to increase community engagement in educating members. For example, casseroleclub.com is a social enterprise that brings together cooks and connects them with people interested in cooking, to increase social engagement and reduce malnutrition. Recent technological advancements have improved the ability to share food. For example, Ganglbauer et al. (2014) explored the use of the FoodSharing.de platform (Figure 5) to facilitate food sharing amongst consumers, farmers, organisations and retailers in order to reduce food waste in Austria and Germany. Their findings showed that FoodSharing.de successfully facilitated the sharing of food amongst large numbers of participating people, as evidenced in 17,000 active users sharing just under 1,800 food baskets within their online community. Their research showed that online social platforms could assist or facilitate in the process of food sharing between communities. Similarly, Grimes and Harper (2008), and Wei and Nakatsu (2012) provide further support for using technology to promote the sharing of food by bringing people together for social interaction and entertainment.

[2] Photo attributed to Thieme (2012).

Figure - 5 Illustrates the FoodSharing.de website.

Further, there are countless mobile apps designed to assist consumers with their everyday food practices. Some are purposed to support the common activities a user undertakes during food purchasing, storage and cooking activities. Public and private investments have capitalised on opportunities to provide greater knowledge of food usage to users and how to manage it within domestic settings, for example, by using recipe and food diary applications (Ene, 2008; Schneider, 2008). Recent design interventions have targeted raising awareness of food waste within communities, such as the Food Waste Diary (Figure 6) and Love Food Hate Waste apps (Figure 7). Changing practices around food and its waste can be difficult. Using technology is only one of many possible ways to facilitate reducing domestic food waste, but an effective one. For example, Lim, Dolech, and Yalvaç (2014) explored a recipe finder embedded within an app and how it helped a community of consumers find new uses for food that would otherwise be discarded. Their approach prevents food from being wasted in two ways: (i) providing information of food usage and increasing the level of food literacy, and; (ii) prompting food consumption before expiry. Their findings indicated that technology can simulate communal meal consumption between two or more people, presenting an opportunity to bring together otherwise separate people through technology.

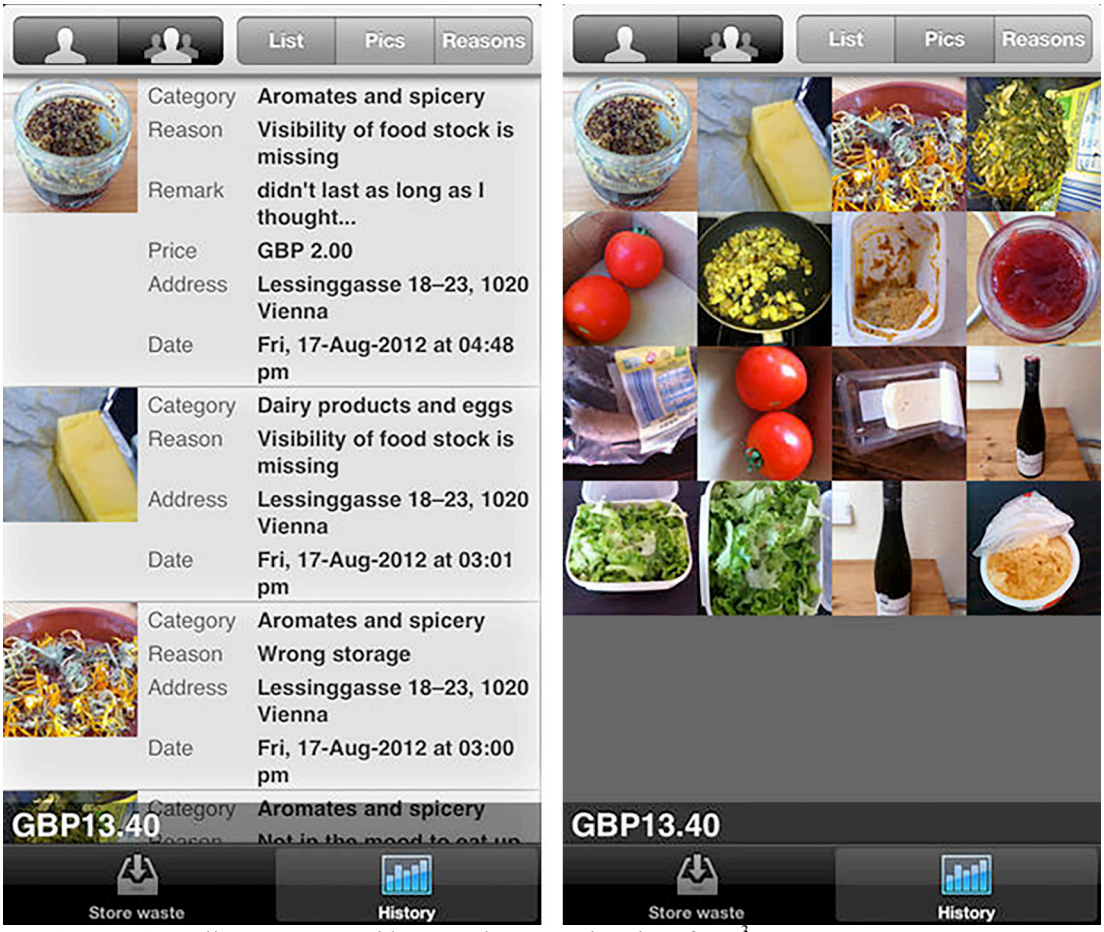


Figure - 6 Illustrates several key Food Waste Diary interfaces[3].

[3] Images retrieved from https://itunes.apple.com/au/app/food-waste-diary/id554162013?mt=8

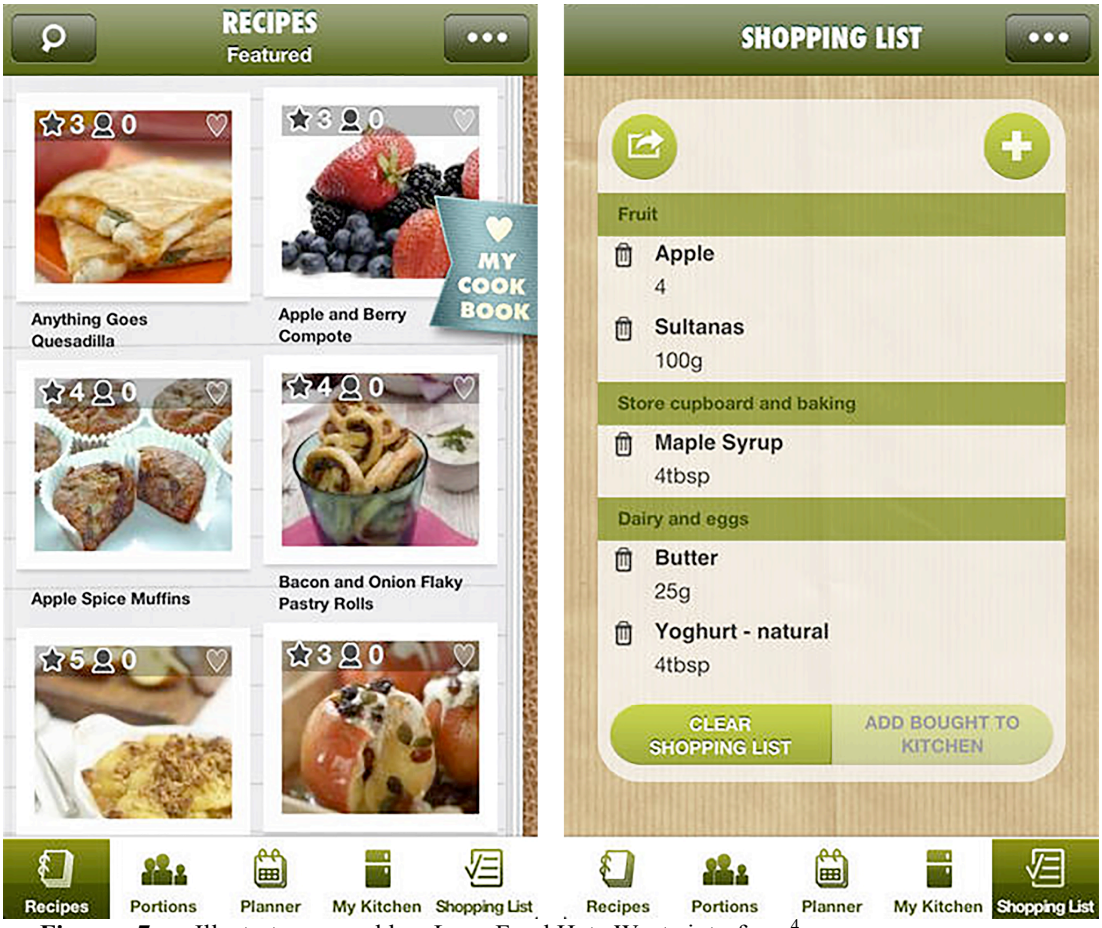


Figure - 7 Illustrates several key Love Food Hate Waste interfaces[4].

Further, Rouillard (2012) investigated how co-locating a mobile device with the household fridge can reduce food waste. In the study, a mobile device was fastened to the fridge for the user to interact with while exploring for food. The technology encouraged the consumption of near-expiry food to reduce waste. Rouillard's (2012) findings showed the co-location of a mobile device could be used to facilitate such a process. They propose several useful technologies that could be embedded with an intervention to assist with designing similar applications: voice, keyboard, camera, barcode scanner, and image recognition to manage data. These are example interventions leveraging HCI to target food sharing and food management.

These sets of literature demonstrate the opportunities for mobile and ubiquitous technologies to assist consumers with their everyday activities, in particular, supporting the reduction of domestic food waste.

[4] Images retrieved from https://itunes.apple.com/au/app/love-food-hate-waste/id578274009?mt=8

2.3.3 Design Considerations

Froehlich (2009) argued that feedback technology systems building on HCI can impact user behaviours leading to reduced energy consumption. Their study identified ten key dimensions that can assist in designing feedback systems that engage users about their energy consumption. Froehlich (2009, pp 4-8) recommended the following dimensions:

- ***Frequency*** *– supporting the link between action and effect, increasing the individual's awareness of the consequences of their actions;*
- ***Measurement Unit*** *– displaying physical data;*
- ***Data Granularity*** *– describing the scope and practicality of the data that the user receives;*
- ***"Push and Pull"*** *– describing the how information be disseminated to the user and relates back to frequency;*
- ***Presentation Medium*** *– describing in what form is data conveyed to the user;*
- ***Location*** *– explaining where the feedback will be provided, locally or independently;*
- ***Visual Design*** *– managing the perceived ease of use (Venkatesh & Davis, 2000) and visual representation of data;*
- ***Recommending Action*** *– prompting users of correct behaviour when particular behaviours are practices;*
- ***Comparisons*** *– providing mechanisms for users to review their performances by comparing them to others;*
- ***Social Sharing*** *– supporting social issues through social networks.*

Many of these dimensions are considered to be of vital importance in the development of technologies that facilitate a change in food-related behaviours (Fang & Hsu, 2010; Froehlich, 2009). While Froehlich's (2009) model was originally developed to encourage shifts in energy consumption patters, it provides dimensions that may be universally applicable to behaviour change. Therefore, if the design dimensions are considered during interventions that encourage a change in consumer

behaviours, a change is expected to occur as a result. Considering this, the model proposed by Froehlich (2009) is used to guide the design of interventions used in this study. Further, Fang and Hsu (2010) extend these dimensions to include an emotionally engaged component, which suggests that influencing an emotional response for a given behaviour will result in a persuasive system that is more likely to lead to sustained behavioural change (Creed & Beale, 2005). In addition, Bishop (2005) explored the topic of motivating users to be more involved in online communities, finding that rewarding participants for their participation encouraged a maintained long-term behavioural change. These further elements are used to guide the design of the interventions used in this thesis.

2.4 SUMMARY OF CHAPTER TWO

The objective of this chapter was to report on a review of literature pertinent to this study. The literature review encompassed a number of domains: (i) food waste, which provided the initial motivation for this thesis, (ii) behaviours and causes of food waste, which provided the current understanding of behaviour-related causes of food waste, (iii) behavioural theories, which provided a theoretical lens to conduct and analyse the research of this thesis, (iv) implications of HCI and opportunities for mobile and ubiquitous technologies to encourage sustainable consumer food practices, leading to the identification of design dimensions that guide the design of the interventions used in this thesis. Several gaps in the literature were raised and are informed by this thesis.

Chapter 3: Methodology

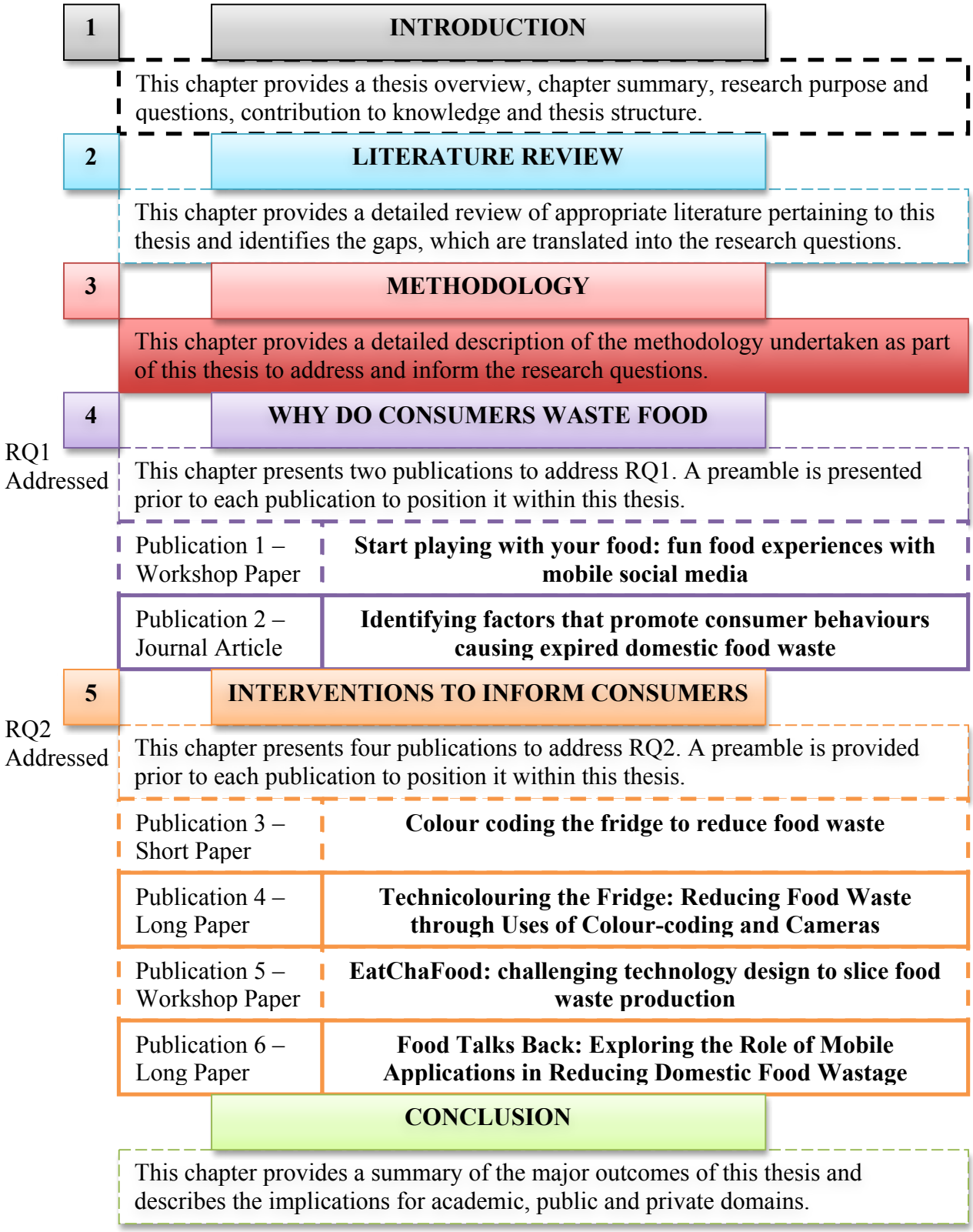


Figure - 8 A visual representation of the thesis structure with a focus on the current Chapter.

This chapter describes the methodological approach used to address the research inquiry of this study. Firstly, the ethical approval of this research and the

position of candidature are presented. This section provides the ethical clearance for the research undertaken as part of this study; it also highlights related work undertaken by colleagues, and where this study is positioned within that related work. The individual studies used together to investigate RQ1 are discussed and include the data collection and analysis methods. Thirdly, the individual studies used together to investigate RQ2 are then detailed as well as the associated data collection and analysis methods.

The Literature Review (Ch. 2, pg. 13) examined the current literature pertaining to food waste, consumer behaviours leading to domestic food waste, and the role HCI can play in reducing domestic food waste. The chapter revealed two underlying gaps in the literature, which present opportunities to explore and investigate. These were translated into two key research questions (RQ) (Ch. 1, Section 1.2, pg. 7). This chapter provides the foundations of the research methodology for investigating the two stated research questions.

3.1 ETHICAL APPROVAL AND POSITION OF CANDIDATURE

The research conducted as part of this thesis was given ethical clearance (QUT UHREC file number 0900001401). The ethical clearance given is for the larger ARC Linkage (LP100100232) funded program of research, entitled *Eat, Cook, Grow: Ubiquitous Technology for Sustainable Food Culture in the City*. This study, which forms one stream of investigation, is part of the overall program of research into food, design, and technology. The research program is part of a global collaboration involving a number of colleagues. The ARC Linkage research program explores urban food practices along the food supply chain, in order to support health, social engagement and playfulness with the food in people's everyday lives. Environmental sustainability is a core component of this larger body of research. This thesis represents the outcomes of one of two PhD projects associated with the ARC Linkage research program. The use of some interventions in this thesis, such as I8DAT, FridgeCam and EatChaFood, have been informed by a collaboration between the PhD candidate associated with this thesis, and Professor Marcus Foth (QUT), Dr Jaz Choi (QUT), Professor Greg Hearn (QUT), Peter Lyle (QUT PhD Candidate), Eva Ganglbauer (Vienna University of Technology, Austria), Professor Geraldine Fitzpatrick (Vienna University of Technology, Austria), and Professor Shaun Lawson (University of Lincoln, United Kingdom). The research design is

applicable for several studies that investigate the research questions. Both the research focus and the methodology were informed by that international collaboration.

3.2 RESEARCH DESIGN

3.2.1 Overview

The research design used in this thesis is detailed in two segments. The first describes the design used in the investigation of RQ1; the second describes the design used in the investigation of RQ2. Where appropriate, the connections between studies, methods, analysis and publications are highlighted.

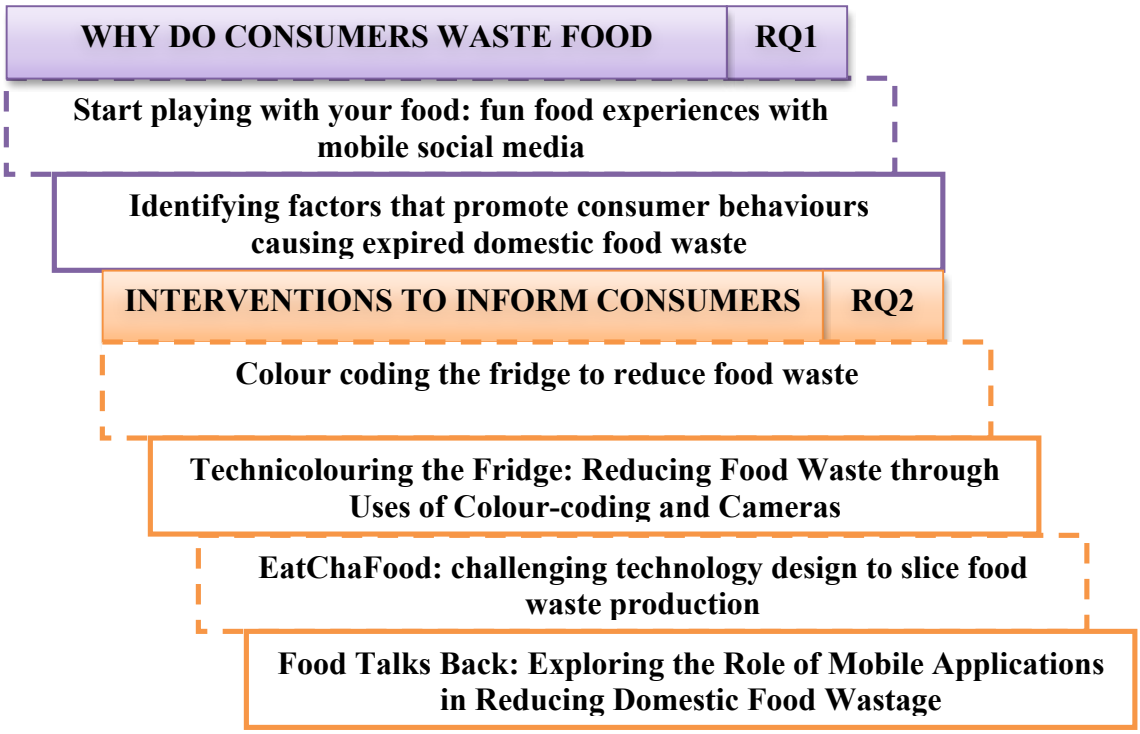


Figure - 9 Illustrates a graphical timeline of the progression of studies implemented to investigate each research question.

3.2.2 Research Design Justification

This thesis is aligned with a social constructivist framework. The justification supporting the use of this framework to guide the research design is presented in this section. Before the justification can be made; a review of interpretivist versus positivist research should be explored in order to determine the characteristics of each approach and the benefits and limitations associated with each approach. The explanation justifies the use of a social constructivist framework for this study. Positivist and interpretivist research each have their own benefits and limitations.

Positivist research is deterministic by nature. Thus, positivist research aims to identify causes that influence outcomes. On the surface, the approach appeared to be viable to apply to this research in order to identify the causes that influence behaviours resulting in food waste. A positivist approach is also reductive, seeking to reduce the number of variables to test into a small discrete set, in order to investigate a hypothesis or research question in an objective manner. The tools used in a positivist framework generally align with quantitative methods, seeking to empirically determine outcomes and measure data through statistical analysis. Positivist research is predominately used to verify or falsify existing theory and often begins with a theoretical standpoint, which is either supported or refuted once data has been collected and outcomes have been identified. Therefore, a positivist approach to this research, while able to assist in identifying a key cause of behaviours resulting in food waste, would not achieve a deep understanding about that key cause and why it had surfaced. Neither would the approach assist in understanding the role of design interventions to encourage sustainable food practices in domestic settings. Positivist research answers questions related to "What" rather than "Why" (Creswell, 2009). In summary, a positivist approach can assist a researcher to identify the impact of one factor on other factors. However, it may not necessarily provide answers to why and how the problem may exist. Consequently, a positivist approach to the research was not chosen.

Interpretivist research seeks to understand the phenomena being investigated, typically through subjective meanings applied to the experiences of the researcher (Creswell, 2009; Denzin & Lincoln, 2005; Patton, 2002). Interpretivist research comprehensively relies on participants' views of a given situation that is being investigated by requiring that the questions being asked of participants are broad in order to provide the participants with the best opportunity to construct their own meaning of what is occurring in the situation. The subjective meanings for individuals are developed over a long period of time. Further, subjective meanings are developed through social interactions, which is why interpretivist research can sometimes be referred to as social constructivism (Creswell, 2009). Interpretivist research normally applies qualitative methods when investigating a phenomena, and the research approach is typically well suited to focus on the complex contexts in which people live, work, and play. A limitation associated with interpretive research

is that a researcher's own personal, social, cultural, and historical experiences will shape their interpretation of a situation. This can lead to bias in providing an understanding of a situation. However, the goal of an interpretivist researcher is to understand the subjective meanings of others about a situation that is under examination, rather than attempting to understand a situation by reflecting on their own interpretations of what is occurring in the situation. Interpretivist research differs from positivist research in that the research is not necessarily limited to understand only what is occurring in a situation, but also why something is occurring and how it is occurring in a situation. Therefore, the benefits of an interpretivist approach enable a researcher to better understand why and how something occurs in a situation. An interpretivist approach differs from a positivist approach in that it does not typically start with a theory to apply to a situation; instead, interpretivist researchers seek to inductively develop a theory or pattern of what is occurring in the situation (Creswell, 2009; Maxwell, 2005).

Choosing between positivist and interpretivist research has obvious implications for the approach: researchers may choose to apply a combination of different types of research methods within a pragmatist framework. Pragmatist researchers use both qualitative and quantitative methods to draw conclusions from their studies. This thesis sought to examine why consumers waste domestic food and how interventions may be domestically situated to influence the factors promoting the consumer behaviours resulting in food waste. Therefore, the research focused on domestic settings, specifically where the participants lived. The research also sought to understand why certain processes were occurring in domestic settings and how particular interventions could be used to affect those processes. Therefore, it was thought that an interpretivist approach (specifically, a social constructivist approach) to the research would be the most appropriate, when considering the time constraints of a PhD project and the nature of what was to be examined as part of the study. Consequently, the methods implemented to investigate the research questions associated with this thesis are predominately aligned with qualitative methods that are well-established in design research.

3.2.3 Research Validity

Research validity refers to the accuracy of research findings. Creswell (2009) argues that qualitative research should employ checks of the accuracy of the findings

to ensure validity of the research. This can be done through various procedures. Maxwell (2005) argues that qualitative research must address various threats to the validity and present ways of reducing those threats. These threats depend on whether the research is qualitative or quantitative. Moreover, similarly to Creswell (2009), Maxwell (2005) suggests that controls can be used to deal with anticipated and unanticipated threats to validity. These include controls such as (i) randomised sampling and assignment, (ii) framing hypotheses before collecting data, and (iii) undertaking tests to determine variables that may be statistically significant. Maxwell (2005) further suggests that how validity threats are dealt with can be a key factor differentiating qualitative from quantitative research. Creswell (2009) argues that methods such as triangulation are effective in reducing validity threats. Maxwell (2005) argues that stating such a method does not serve to actually reduce the threat of validity, because the method is too broad in context. Instead, Maxwell (2005) suggests that specific threats to validity should be highlighted and a discussion provided about how those threats are addressed as part of the research design.

The researcher's bias and reactivity are two important threats to the validity of qualitative conclusions. Bias refers to the choice of data used to match a particular theory or the notion that specific data stood out and is found to be important to the researcher. Maxwell (2005) argues that the observations made by the researcher should be noted in the context of their values and expectations, which could influence how the study was conducted or the conclusions were drawn. Reactivity refers to the influence of a researcher on a particular setting, where the study is undertaken or the participants involved in the study. Rather than trying to mitigate reactivity as a threat to validity, Maxwell (2005) and Creswell (2009) suggest the researcher tries to understand their influence in order to use it productively. However, Maxwell (2005) suggests a researcher is much less of an influence on participants' behaviours during participant observation studies. For interviews, on the other hand, Maxwell (2005) argues that the researcher's influence on participants is inevitable, and it is important to understand how the participant is being influenced in each situation, and report it. The following points describe several mechanisms that Maxwell (2005) suggests are useful in alleviating threats to validity.

- ***Rich understanding of what is occurring*** *– the researcher can obtain this through intensive interviews that provide a satisfactory level of detail and*

variation to expose a full depiction of what might be occurring in a situation.

- ***Participant involvement and validation about conclusions drawn*** *– the researcher can share their interpretation of what a participant has said in order to verify that the interpretation of the researcher aligns with that of the participant (Lincoln & Guba, 2000).*
- ***Intervention targeting specific practices*** *– the researcher can use quasi-experiments to intervene current practices in order to confirm if an initial hypothesis is found to be true.*
- ***Triangulation*** *– the researcher can use a number of methods to collect information from participants who have differing backgrounds and come from different circumstances.*
- ***Quasi-statistics to quantify some findings*** *– the researcher can employ quantitative methods to collect implicit information in order to support conclusions derived from the qualitative analysis.*
- ***Comparison of studies to draw similarities and differences*** *– the researcher can implement several studies in order to compare and test the conclusions derived from each study.*

These control mechanisms have been used in this study to help guide the research design and have been specifically integrated into the individual research activities. For example, a convergent interview process was implemented as part of this study to provide a rich understanding of why consumers waste domestic food. This process was also supported by participant observations that help to confirm the outcomes. Further, several research activities were used in conjunction to compare the outcomes derived from the activities. For example, the Colour Code Project and FridgeCam research activities were compared to provide an understanding of the more effective approach to reducing domestic food waste by improving consumer knowledge of either their food supply or food location. In addition, the Colour Code Project and FridgeCam, in conjunction with LeftoverSwap, FridgePal, and EatChaFood, are used as interventions that were designed to test the outcomes of the convergent interview process and participant observations. Each research activity employed several methods of data collection to triangulate themes. However,

triangulation was not employed in the traditional sense. Instead, several qualitative methods were used to examine participants from a variety of backgrounds in order to derive meaningful outcomes. These methods together provided a rich understanding of the occurrences in the situation being examined. Further, quantitative methods, such as a survey and statistical manipulation, were initially used in the first research activity of this thesis to gather useful information regarding key variables that might be useful to examine in the remaining research activities. Participants were also encouraged to provide feedback on the conclusions drawn throughout each research activity. These control mechanisms have been implemented as part of the research activities forming this thesis in order to ensure that potential validity threats have been appropriately addressed and the risks of threats to validity are low.

3.3 WHY DO CONSUMERS WASTE FOOD (CHAPTER 4)

3.3.1 Overview

This segment details two inter-independent and sequential research activities used in conjunction to investigate and inform RQ1. The research activities were undertaken to provide extensive insights into consumer behaviours so as to determine why consumers waste food in domestic settings. Specifically, they sought to identify key factors promoting consumer behaviours prone to generating domestic food waste (Table 1). The first research activity, I8DAT (Publication 1), engaged individuals through a web-based visual ethnographic diary. Specifically, the website, used as a pilot study, sought to provide clarification and insight into key variables that might be most appropriate to measure for the future research activities investigating RQ1.

The second research activity involved two complementary phases of data collection methods to investigate RQ1: a *convergent interview process (CIP)* and *ethnographically inspired participant observations (EIO)*. However, it used the findings from I8DAT (first research activity) to guide and inform the direction of each phase of data collection. The outcomes of the CIP provided key themes, which translated into factors promoting consumer behaviours leading to domestic food waste. The outcomes of the EIO confirmed the identified factors that promote consumer behaviours leading to food waste. In addition to the two main data collection methods, a further two methods of data collection were undertaken: *interviews* and *visual ethnography*. These methods provided further support and

strengthened the outcomes of the EIO. These research activities were used in conjunction to investigate and inform RQ1 (Figure 10).

RQ1 – Research Activities Summary

Research Activity	Description	Research Question	Data Collection Methods	Analysis Methods
(1) I8DAT	Pilot study used to clarify important variables appropriate to measure for future RQ1 related activities	How is food waste characterised in domestic settings?	- Meal Diary - Focus Group - Short Survey - Long Survey	- Shared Visual Ethnography - Thematical Analysis - Statistical Analysis
(2) CIP & EIO	CIP provided key themes that were translated into factors	Why do consumers waste domestic food?	- Convergent Interviews	- Thematical Analysis
	EIO sought to confirm the identified factors and answer RQ1		- Participant Observations - Interviews - Visual Ethnography	- Thematical Analysis - Visual Ethnographic Techniques

Table - 1 Provides a summary of the two research activities that are used in conjunction to investigate and inform RQ1.

Figure - 10 Illustrates a graphical representation of the two publications detailing the research activities used to inform RQ1.

3.4 RESEARCH ACTIVITY 1: I8DAT (PUBLICATION 1)

3.4.1 Background

Online social media has had a significant influence on how people and communities connect with one another over the past few decades. This has further given rise to the development of technology that shines light on more intimate and private information sharing. Food is one such example. Food is an extremely personal and intimate part of our lives. I8DAT was developed as a tool to leverage social media to share information about an individual's eating experiences. It gathers data through a shared visual ethnographic process, allowing for a rich preview of food preparation, cooking and waste management in the household, while encouraging social discussion around each of these processes. I8DAT was deployed in two separate locations, including South-East Queensland, Australia and Lincoln,

UK. The findings used for the purposes of this PhD consisted of data collected in Australia only.

3.4.2 I8DAT Positioned within this Thesis

I8DAT was a tool used as part of the larger ARC Linkage program of research, which this study is associated with, to observe the practices of everyday people when interacting with food. For the purpose of this study, I8DAT provided an initial insight into several fundamental variables that were most appropriate to examine in further undertaken studies. An emphasis was placed on demographics, purchasing patterns, household income, food interactions and food waste production and management during an activity's analysis, highlighting the importance of these variables. It was thought these variables would most adequately provide information that would support and guide the research direction this follows.

While I8DAT was used as a pilot study, the activity was the first undertaken as part of this thesis. It assisted the process of narrowing the research design to align with achievable research goals. While I8DAT had a broader goal and research question associated with the larger ARC Linkage, the question this thesis sought to draw conclusions from by using I8DAT was: *How is food waste characterised in domestic settings?*

3.4.3 Data Collection and Analysis

The research activity employed the use of *shared visual ethnography* (Choi, 2010) to capture a food diary, so as to explore food consumption practices beginning with: (i) meal preparation, (ii) the cooked meal, and (iii) the leftovers (aftermath). The study targeted 15 participants who used the website to share information about their cooking experiences. A *focus group* of the 15 participants was also conducted to provide a greater understanding of participants' use of the website to share user's cooking experiences with others. This focus group engaged 7 of the 15 participants who actively used the I8DAT website. The statements given by the focus group underwent thematic analysis so that the emerging themes could be used to inform the next stage of data collection for addressing RQ1.

Additionally, the research activity was reinforced with two surveys: (i) a *short survey* of 50 participants from the general public, which asked general questions about the participant's food usage, interaction and waste habits, and (ii) a *descriptive*

broader survey of the 15 participants who actively used the I8DAT website, which consisted of 33 open-ended questions. The questions asked participants about their thoughts, use and interaction with food, growing food, consumption and food waste patterns. The short survey underwent statistical analysis to derive similarities and differences in responses across surveys. The second, longer, survey used a combination of statistical analysis of the multiple-choice response and thematic analysis of the descriptive responses, in order to derive key variables that would be useful for future research activities. The outcomes from the analysis of findings from each data collection method were used to guide the following research activity used to inform RQ1.

3.5 RESEARCH ACTIVITY 2: CONVERGENT INTERVIEW PROCESS (CIP) AND ETHNOGRAPHICALLY INSPIRED PARTICIPANT OBSERVATIONS (EIO) (PUBLICATION 2)

3.5.1 Background

It was identified in Chapter 2: Literature Review that the majority of interventions targeting reduced domestic food waste pursue this goal through several avenues. Some interventions aim to improve a consumer's level of food literacy, so as to encourage the use of food items that may otherwise be wasted because of a lack of knowledge of how to use those items. Some interventions aim to heighten consumer awareness about the practices they are currently performing, which are prone to resulting in food waste. Other interventions provide perceived direct action, offering methods to assist with food waste reduction. However, none of these interventions have sought to target the factors or circumstances that promote consumer behaviours resulting in domestic food waste. This is because the reasons why consumers waste domestic foods are largely still unknown. Therefore, this research activity sought to identify the factors promoting consumer behaviours resulting in domestic food waste and was subsequently guided by RQ1.

3.5.2 Data Collection and Analysis

Two phases of data collection were used to investigate the research question and were conducted sequentially over a three-month period. For both phases, participants were recruited from a survey disseminated to the general public through social media and email. Participants in both phases underwent a screening process before they were recruited.

Firstly, a convergent interviews process (CIP) (Dick, 1990, 2000) was conducted. The CIP engaged 12 participants (Table 2). Participants were recruited based on a dissimilar combination of their age, sex, living arrangements, working arrangements and household type, as required in a convergent interview protocol (Dick, 1990, 2000). The procedure consisted of a series of open-ended questions relating to five main areas: grocery shopping practices and experiences, food storage practices, household cooking habits, food waste management practices, and food waste prevalence. Interviews took 45 minutes on average, and participants were encouraged to add further details they thought relevant. These details were then converted into questions and integrated into future interviews. The CIP took place over a four-week period. During this time, participants were continually recruited until theme saturation occurred and no new themes surfaced. *Thematical analysis* (Creswell, 2009; Given, 2008) was applied to the interviews to derive emergent underlying themes.

CIP Participants Summary

No.	Participant Description	Shopping Habits	Living Arrangements	Food Waste Production
C1	22 year old female actress	One large shop a week	Shared household	One or two vegetables a week
C2	40 year old professional male	Several small shops through the week	Family household (including a partner and child)	A 5L bin's worth a week
C3	30 year old professional female	One small shop a week	Shared household	A 5L bin's worth a week
C4	77 year old female pensioner	Make regular shops per week	Three bedroom house – live alone	One or two vegetables a month
C5	26 year old professional male	Per meal shopping (several small top up shops a week)	Family household – live with parents	One or two items a week
C6	19 year old male university student	As-needed shopping	Unit – live with sister	No items
C7	29 year old female student nurse	Once a week large shop with several small shops throughout the week	Couple household	A 5L bin's worth a week.
C8	28 year old male PhD student, sessional academic	Once a week large shop with several small shops throughout the week	Couple household	A 5L bin's worth a week.
C9	37 year old female professional	Several small shops through the week	Family household (including a partner and child)	A 5L bin's worth a week
C10	31 year old female PhD student	Per meal shopping (several small top up shops a week)	Couple household	One or two vegetables a month
C11	28 year old male professional	Per meal shopping (several small top up shops a week)	Couple household	One or two vegetables a month

C12	41 year old female PhD student	One large shop a week, two small shops a fortnight	Family household	Several vegetables a week

Table - 2 A description of the similarities and differences between DC1 participants.

The ethnographically inspired participant observations (EIO) followed the CIP as the second phase of data collection to investigate RQ1. The EIO engaged 6 households comprising 17 individuals (Table 3). The EIO initially employed similar restrictions for recruitment as with the CIP. However, the households that were initially approached expressed reluctance to become involved in the study because of the intensive and personal nature of the observations, which made us reduce the original restrictions to only require more than one occupant per household in the EIO. This allowed us to examine external and contextual forces that may surface, which might be significant in influencing household behaviours regarding food with respect to the four considerations of the VBN theory: (i) Attitudinal factors, (ii) External or contextual forces, (iii) Personal capabilities, and (iv) Habit or routine (detailed in Chapter 2: Literature Review).

The EIO followed the progression of food during the consumer phase of the food lifecycle over a four-week period. This entailed observing household practices during post-purchasing (receipt), storage, and consumption of food. It also required observing waste management practices. Five questions guided observations:

a) What shopping practices do households employ?

b) What do consumers characterise as expired food?

c) How do consumers handle expired waste?

d) What quantity of expired waste do households produce?

e) Is a system of food organisation practiced when households store food?

Addressing these questions involved a five-stage process:

1) The collection of shopping dockets;

2) Taking photos of the inside of the fridges;

3) Examining the contents of a bin (provided to households) that contained the expired food waste accumulated over one week;

4) Weekly informal interviews;

5) A final debrief interview that was carried out once at the conclusion of the study.

EIO Households Summary

No.	Household Type	Living Arrangements	Number of Occupants in Household	Shopping Habits	Household Income
H1	House	Family household	Three (including a child)	One big shop a week, with one or two small top up shops	>$200,000pa
H2	House	Family household	Three (including a dependant adult)	One big shop a week	>$200,000pa
H3	Apartment	Couple household	Two	One big shop at the markets a week, with several small top ups	$80,000pa
H4	Unit	Shared household	Three (a couple and a house mate)	Several small shops a week	>$150,000pa
H5	Apartment	Couple household	Two	One moderate shop a week, with several small top ups	$80,000pa
H6	House	Shared household	Four	Two small shops a week	>$100,000pa

Table - 3 A description of defining characteristics of each DC2 household (Publication 2).

With the exception of the final interview, each component was actioned once a week in the participant's home, with questions directed at a single household representative who had been chosen by all household residents. The interview questions addressed the participants' experiences regarding their food purchasing, cooking, consumption, and waste management practices. Fridge photos applied *visual ethnographic techniques* (Choi, 2010; Pink, 2007; Schwartz, 1989) to examine the subtle differences in storage patterns adopted by households. Fridge photos additionally illustrated the movement of food and provided contextual insights about interactions consumers had with their food. This assisted the process of examining what consumers characterise as food waste. The collection of shopping item lists and shopping receipts depicted an approximate inventory of food for households. This, in conjunction with interview responses, helped us to identify household shopping practices.

Final interviews in the EIO explored the experiences of all household residents and comprised of open-ended questions, concerning three areas: (i) The experiences of consumers during the study; (ii) The impression of consumers whether they felt the study had an impact on their awareness of their food shopping, storing, consumption, and waste management practices; (iii) Suggestions for technologies

that may encourage reduced expired domestic wastage in the future. The outcomes of this research identified three major contributing factors promoting consumer behaviours that result in domestic food waste. Two minor factors were also identified (discussed in Chapter 4: Why Do Consumers Waste Food).

3.6 INTERVENTIONS TO INFORM CONSUMERS (CHAPTER 5)

3.6.1 Overview

This segment details *four* sequential research activities used in conjunction to investigate and inform RQ2. The research activities were undertaken to examine their impact on consumer behaviour (Figure 11). However, the overall goal of the combination of the research activities was to explore ways to (i) encourage a shift in domestic consumer behaviour by providing a greater knowledge of food supply, location and level of food literacy, and (ii) help facilitate food sharing by using mobile applications to encourage food consumption before expiration (Table 4).

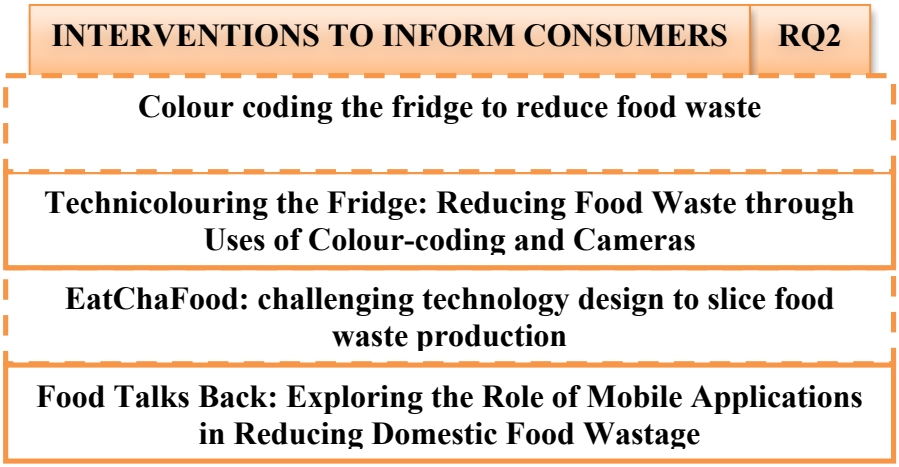


Figure - 11 Illustrates a graphical representation of the four publications detailing the research activities used to inform RQ2.

The first research activity, the **Colour Code Project,** sought to target one of the three major factors identified as a result of the investigation of RQ1: *Current household food item location knowledge* – do people know where to locate food items in their storage? In doing so, the Colour Code project engaged participants through the use of a colour code scheme, which was implemented within the participant's household refrigerator. The research activity was used to inform part of RQ2, and subsequently addressed the sub research question: *Does the organisation of a colour scheme for different food types in a household refrigerator raise the awareness of available foods for all members in the household and does this*

consequently lead to a reduction in expired food waste? The outcomes of this research activity revealed that a colour scheme provided a system of food storage within the household refrigerator, which assisted participants with easily locating items, and keeping the fridge tidy. A subtle but noticeable decrease in food waste was also noted.

The second research activity **FridgeCam,** followed. FridgeCam sought to target the second major factor identified as a result of the investigation of RQ1: *Current household food supply knowledge* – do people know the available food items in their storage? The FridgeCam activity provided users with a camera that took photos of their household's fridge interior. The second research activity was used in conjunction with the first research activity, The Colour Code Project, to identify how interventions can be integrated within the domestic fridge to improve a user's food supply and location knowledge. The outcomes of this investigation are noted in Publication 4 (Ch. 5, Section 5.2, pg. 101). The publication informs RQ1 through investigating the sub research question: *How can situated interventions targeting the domestic fridge provide users with improved food supply and location awareness to encourage changes towards sustainable food practices?* The outcomes of the investigation identified a number of recommendations for HCI practitioners to consider when designing interventions targeting improved food supply and location knowledge. A further outcome indicated that improving food location knowledge would have more of an influence with reducing domestic waste than improving food supply knowledge.

The third research activity, **EatChaFood**, is the third design intervention of this study and seeks to address all three identified factors resulting from the investigation of RQ1. It does this by implementing some of the successful characteristics identified in the previous two interventions: The Colour Code Project and FridgeCam. EatChaFood is a mobile application developed as part of this thesis that provides users with a list of their (i) food supply, (ii) the location of food, and (iii) supports users in gaining a greater understanding of their food, thereby improving their food literacy. The research activity was used to inform part of RQ2 and responded to a design challenge to improve how users can use mobile technology to increase knowledge of their food supply and location awareness, and to improve their food literacy. The outcomes from this study identified some of the

barriers that can be experienced when designing mobile application to encourage sustainable food practices.

The fourth research activity involved an investigation of the use of two mobile applications: **LeftoverSwap and Fridge Pal**. LeftoverSwap[5] sought to investigate the effectiveness of a commercially available mobile application to facilitate the sharing of food between a known community of people, in order to reduce expired food waste. Fridge Pal[6] sought to investigate the effectiveness of a commercially available mobile application to improve food supply and location awareness of users, and to assist users in utilising food that may have otherwise been wasted by providing useful recipes. The fourth research activity was used in conjunction with the third research activity, EatChaFood, in order to investigate how domestically situated interventions can provide facilitation of food sharing and improve consumer awareness of food supply, location and literacy to encourage changes towards sustainable food practices. The outcomes of this investigation are noted in Publication 6 (Ch. 5, Section 5.4, pg. 121). The publication informs RQ2 by investigating the sub research question: *How can mobile applications help facilitate food sharing and improve consumer knowledge regarding food supply, location and literacy to promote changes towards more sustainable food practices within domestic environments?*

RQ2 – Research Activities Summary

Research Activity	Description	Research Question	Data Collection Methods	Analysis Methods
(1) The Colour Code Project	Colour code scheme to improve food location knowledge	*Does the organisation of a colour scheme for different food types in a household refrigerator raise the awareness of available foods for all members in the household and does this consequently lead to a reduction in expired food waste?*	– Interviews – Visual Ethnography	– Thematical Analysis – Visual Ethnographic Techniques
(2) FridgeCam	Photos to improve food supply knowledge	*How can situated interventions targeting the domestic fridge provide users with improved food supply and location awareness to encourage*		

[5] https://itunes.apple.com/au/app/leftoverswap-find-share-food!/id709466907?mt=8
[6] https://itunes.apple.com/au/app/fridge-pal-shopping-lists/id496451091?mt=8

		changes towards sustainable food practices?		
(3) EatChaFood	Mobile application to improve food supply and location knowledge, and increase a users level of food literacy. Investigate initial insights into food sharing	*Responded to a design challenge to improve how users can use a mobile technology to increase knowledge of their food supply and location awareness, and improve their food literacy.*		
(4) LeftoverSwap & Fridge Pal	Mobile Applications to facilitate food sharing and improve food supply and location knowledge, respectively.	*How can mobile applications help facilitate food sharing and improve consumer knowledge regarding food supply, location and literacy to promote changes towards more sustainable food practices within domestic environments?*		

Table - 4 Provides a summary of the four research activities that are used in conjunction to investigate and inform RQ2.

3.7 RESEARCH ACTIVITY 3: THE COLOUR CODE PROJECT (PUBLICATION 3)

3.7.1 Background

The research activity focuses on designing an intervention within the context of the household refrigerator. This has been found to be the best location for an intervention after previous research activities investigating RQ1 identified the household fridge to be the major contributor to the total household food waste in comparison to the pantry or freezer storage locations. This research activity engaged people by encouraging them to think about where they place items of food in the refrigerator by organising the different food items into clearly defined areas, where specific colours represent each food type. The subsequent research premise of this activity, which is used to inform RQ2 was *Does the organisation of a colour scheme for different food types in a household refrigerator raise the awareness of available foods for all members in the household and does this consequently lead to a reduction in expired food waste.*

3.7.2 Data Collection and Analysis

Guided by a user-centred design approach, members of households were recruited to participate in this activity from responses received to an online survey conducted as part of the previous research activity (Ch. 5, Section 5.1, pg. 94),

disseminated to everyday Australian grocery people and through the professional and social networks of the researcher of this project. In total, 7 households were recruited for this study: 4 couple households, 2 family households with 1 and 2 children respectively, and 1 shared household comprising 3 people. Recruited members of households represented a spread across a range of demographics. Their occupations included a range of full-time roles in private and public sectors; full-time and part-time students; and full-time stay at home parents. Full-time workers represented the majority of participants and were often busy people. Our screening survey revealed that participants differed quite significantly in their shopping frequencies and the places they shopped for food (this included local food markets, IGA, Coles, Woolworths, and local grocers). A small portion of the participants purchased food knowing exactly what they planned to eat the following week (until their next shop), whereas other participants would purchase 'opportunity' food that they thought they might like to eat throughout the week or what could be used in meals. Participants were located across South-East Queensland, Australia.

The study took place over a four-week period. The first two weeks were used to gauge the average quantity of expired food waste produced per week. Participants were encouraged to either write the product name and quantity in a journal or take a photo of products that they threw away to assist in this process. At the end of the second week, the colour code scheme (described below) was implemented and the study continued for a further two weeks to gain insight into how the system was used and its effectiveness in reducing food waste. All participants were asked to customise their preference for which colours would correspond to each food type.

Interview protocols and *visual ethnography* (Pink, 2007; Schwartz, 1989) were used as qualitative data collection methods. Informal interviews were conducted once a week at the participants' houses. Emergent themes were derived from the qualitative analysis of the interviews. Questions were directed at a household representative who was chosen by all household members. Questions related to four main areas:

- *The quantity of food from the fridge, which had expired that week;*
- *The level of difficulty which participants' had in locating food items in the fridge;*

- *The influence the colour code scheme had on their shopping patterns;*
- *The difficulties or barriers experienced by participants' from using the colour code scheme.*

At each interview, the researcher took photographs of the refrigerator. The photos were a mechanism to not only view the movement of food within the context of the refrigerator and to view participants' engagement with respect to the colour code scheme, but also to corroborate what participants were stating in their interviews. In addition, participants were encouraged to either take a photograph or write down a list of all expired products that were thrown away each week and the quantity associated with that product. This was to assist in gauging the quantity of expired food waste in order to see whether the colour code scheme provided an impact on expired food waste.

A formal debriefing interview conducted at the end of the study involved all members of the household. This interview covered the experiences of all participants involved in the study. The formal interview protocol comprised five main questions, each intended to provide insight into participants' thoughts and experiences with the colour-coding scheme, longer term practicality, impact on participants' awareness of food items, possibilities for technology integration, and thoughts on how intensive they found their participation.

The colour code scheme entailed using seven different coloured pieces of opaque plastic that were matched (by the participant) to a corresponding food type. The different food types available for a participant to select from included: *Fruit and Vegetable Produce, Dairy, Condiments, Meat, Bread/Baked Goods, Drinks, and Leftovers*. The different food types were determined by results from the previous studies showing that participants tend to conceptualise the items in their fridge into groups, similar to their grocery shopping experience. The coloured sheets of plastic were cut using common household tools and blue tack was applied to the sheets to ensure they would stick to the shelves of the fridge for the duration of the project. Figure 12 illustrates the state of a participant's fridge before the application of the colour code scheme and the resulting organisation of food items once the colour code scheme was applied.

Figure - 12 Illustrates a participant's fridge before and after the colour scheme was applied.

Finally, a 'map' was drawn up of the configuration and printed on an A4 sheet of paper, then stuck to the front of the fridge (Figure 13). This enabled any member who was about to open the fridge door to know in which direction to look for the food type they were after. Participants were asked to customise the colour scheme and change the colour scheme as they saw fit over two weeks. The outcomes of this research activity showed that food location knowledge was key to reducing domestic food waste, informing the second research activity, which addresses RQ2.

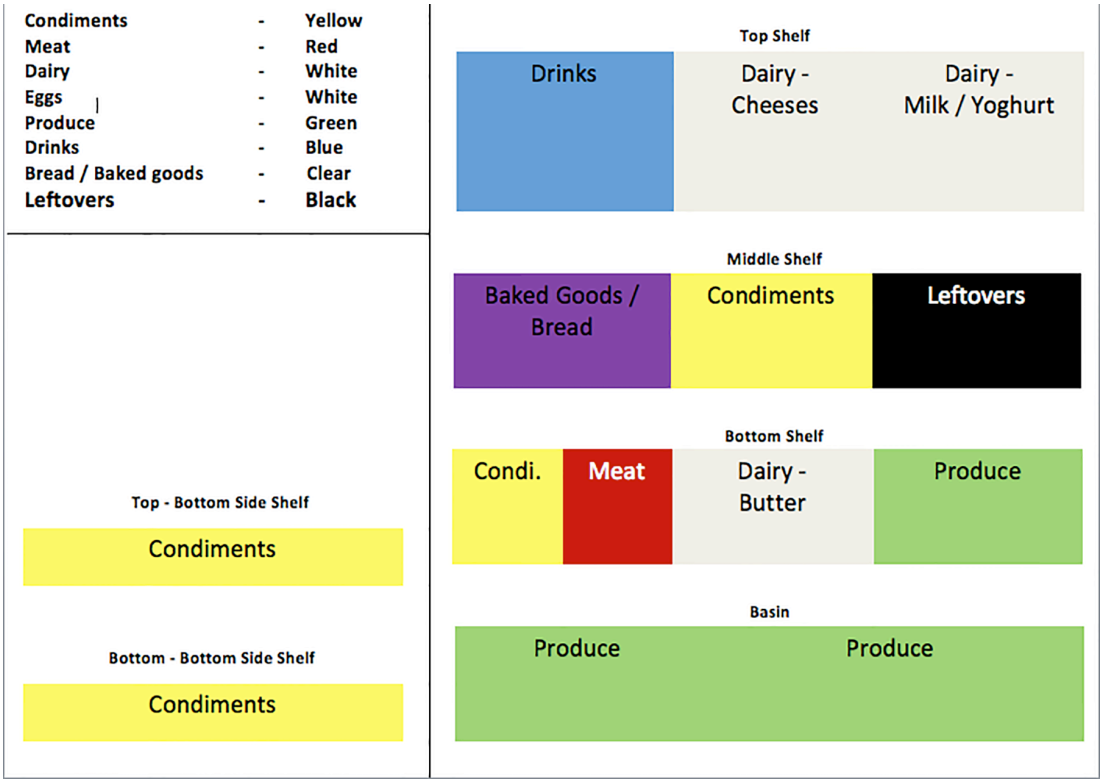


Figure - 13 Illustrates the colour code map of the participant in Figure 12.

3.8 RESEARCH ACTIVITY 4: FRIDGECAM (PUBLICATION 4)

3.8.1 Background

This research activity used the outcomes from RQ1 to explore two HCI interventions and how they may be used to increase the benefits to users and overcome the shortcomings of previously failed technologies, such as the Internet Fridge. Firstly, we investigated FridgeCam and its influence in raising a user's awareness of their food supply. Secondly, we used the findings from the initial Colour Code Project to examine how food location knowledge can be improved to reduce food waste. These interventions are guided by the research question: *How can situated interventions targeting the domestic fridge provide users with improved food supply and location awareness to encourage changes towards sustainable food practices?* The outcomes of this research activity are discussed in Publication 4 (Ch. 5, Section 5.2, pg. 101).

FridgeCam was originally used as a technology probe to reveal more about everyday domestic food practices (Ganglbauer et al., 2013). In our study, we used FridgeCam to improve an individual's knowledge of their domestic food supply. We examined the Colour Code Project and how it can be implemented to improve an individual's knowledge of the location of food. For FridgeCam, we recruited

participants from our social and professional networks. While recruits were known to have a familiarity with the researchers, we ensured study candidates underwent a screening process that noted household type, income and number of household residents before being selected to participate. We excluded candidates if the number of residents within their household was less than two. We did this to specifically examine couple, shared and family households. Further, smaller sample sizes comprising between 3 and 5 participating design evaluators are identified to be more effective than larger groups in providing useful design evaluations (Nielsen & Molich, 1990). Therefore, we elected to limit the sample sizes based on the sample sizes recommended by Nielsen and Molich (1990).

The FridgeCam intervention, implemented over four consecutive weeks, was accompanied by observations and brief interviews with a designated household representative, selected by the household. We encouraged participants to provide comments and feedback of their intervention usage during the brief interviews. We conducted a final interview on conclusion of each study in which each participant was asked opened-ended questions regarding their intervention usage. *Thematical analysis* was applied to evaluate the interview data. We applied *visual ethnographic techniques* (Pink, 2007; Schwartz, 1989) to better understand the movement of food observed in the FridgeCam photographs. We also encouraged participants to take photographs when they felt a photo might show a significant occurrence, determined by them. In both cases, interviews were thought to be the best mechanism to provide a rich understanding of the impact of each study to raise food supply or location awareness. We later cross-examined the interview responses with associated photographs to corroborate what was said.

3.8.2 Data Collection and Analysis

FridgeCam is an application installed on an Android device and secured to the inside of a fridge door to take several photos of a fridge interior each time the door is opened. Photos were made available to household occupants at a specified web address (mobile accessible). On visiting the address, occupants were provided with the 15 most recent photos uploaded by FridgeCam. The FridgeCam device was installed the first week of commencement. The photographs taken by FridgeCam (Figure 14) were used to ascertain the management of refrigerated food and the time spent searching for items. The final interviews with FridgeCam participants

addressed four areas: (i) the influence photos had on shopping practices, (ii) the impact to participants' food supply awareness, (iii) the participant's perceived impact on food waste, and (iv) the different locations photos were utilised and the barriers to using them. We recruited 7 households in total (equalling 10 individuals) to use FridgeCam (see Table 5). Three households (a total of 6 individuals) discontinued the study after the first week of implementation for reasons including technology issues and conflicts of interest. Four remained until the study completed. Three of the four households involved in the FridgeCam study had also participated in the Colour Code Project two months prior to the FridgeCam study commencing. We ensured all materials from the Colour Code Project were no longer in use by those who commenced using FridgeCam to ensure equal conditions for all participants.

Figure - 14 Illustrates FridgeCam photos taken of several participants' fridges.

FridgeCam Households Summary

No.	Household Type	Living Plan	Number of Occupants in Household	Occupations of Residents in household	Household Income	Shopping Practices (per week)
F1	Unit	Shared household	Two	Full-time workers (9pm-5pm)	$80,000 per annum	One large shop
F2	House	Family household	Three (including a child)	Full-time worker (9pm-5pm) & stay-at-home parent	$70,000 per annum	One large shop and several top-up shops
F3	House	Couple household	Two	Full-time workers (9pm-5pm)	$90,000 per annum	Several small top-up shops
F4	Unit	Shared household	Three (a couple and a house mate)	PhD student & 2 full-time workers (9pm-5pm)	$110,000 per annum	Several small top-up shops

Table - 5 Describes each of the households involved with using FridgeCam.

3.9 RESEARCH ACTIVITY 5: EATCHAFOOD APPLICATION (PUBLICATION 5)

3.9.1 App Design and Development

EatChaFood is a mobile application that provides a single account for all members of a household, and household data is stored online. Upon logging in, users are provided with an initial view of the interior of the household refrigerator. The

photo is taken regularly by a camera installed within the household fridge (Ganglbauer et al., 2013). Overlaid on this photo is a colour configuration specific to the household's fridge (Figure 15a). The colour configuration is editable by any household member. Each colour represents a food type (e.g., green refers to fresh produce) and the location where a user will find a food item. Sliders enable users to increase or decrease the transparency of the overlay, enabling the user to view items in their fridge interior without obstruction.

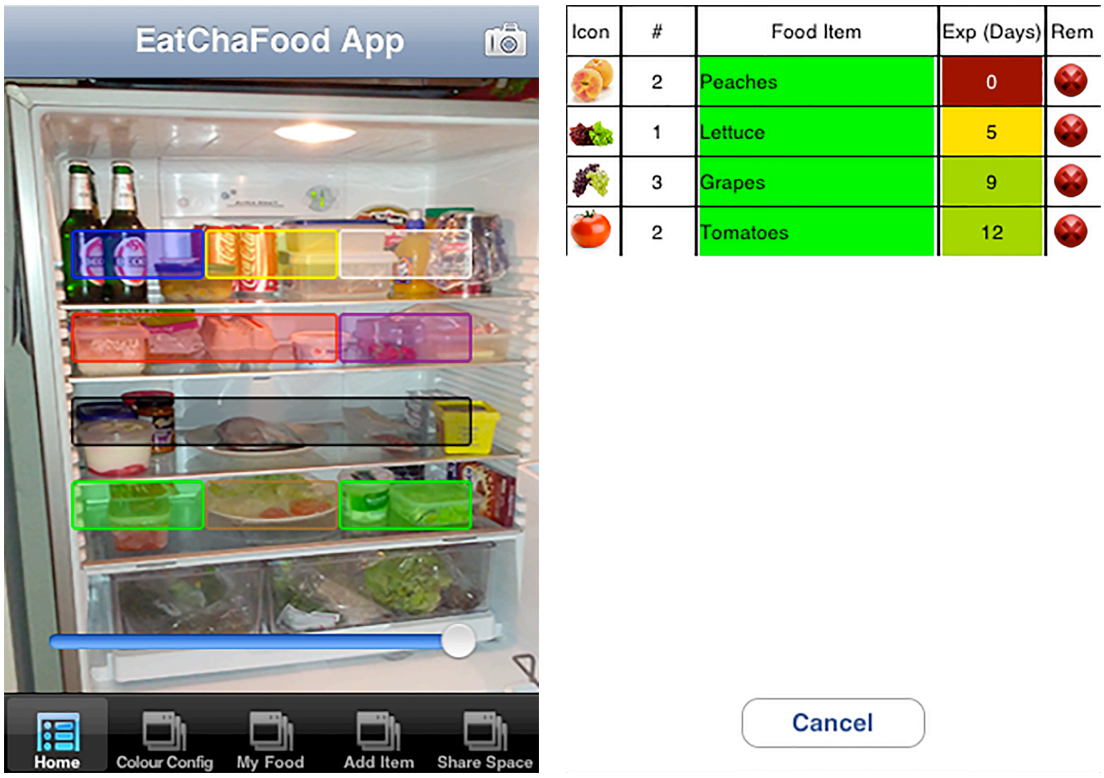


Figure - 15 Illustrates the colour configuration overlaying the fridge interior photo (a) and a user's food inventory (b).

As food expires, the relevant section of the overlay would flash to alert the user. Selecting that section takes the user to a list of products for the corresponding food type. The user is given the option to view a full list of their inventory ordered by food type. Either option provides users with more details about each product with items ranked by expiry date (if available) (Figure 15b). Users can delete items when they are consumed and are also able to find a recipe that incorporates the items. Both the visual representation and detailed list of food stocks increase a user's knowledge of their currently available food supply. Furthermore, the colour-coded representation of item locations increases a user's awareness of where they can locate food items. The recipe system assists users in learning new ways to use their food before it expires. The expiry system provides users with assistance to: (i) know

how long food should last when refrigerated, and (ii) to use their senses when determining if food is edible if it has passed expiration.

To ease the burden of manual data entry, a two step click-through process has been introduced, a user selects a food type, then the food item and quantity. Extra features to be trialled that may justify the current burden of data entry include an advanced system that matches recipe suggestions to available food items as well as allowing for personal recipe variations to be shared with others; communicating the availability of excess food items to friends or neighbours and publishing of fridge inventory lists or photos with other users for comparison or social purposes, such as potluck dinners. An evaluation of this process was undertaken in the following research activity.

3.10 RESEARCH ACTIVITY 6: EVALUATION OF MOBILE FOOD APPLICATIONS (PUBLICATION 6)

3.10.1 Background

The research activity focuses on three mobile applications: Fridge Pal, LeftoverSwap and EatChaFood. These are used in conjunction to inform RQ2 by investigating the sub research question: *How can mobile applications help facilitate food sharing and improve consumer knowledge regarding food supply, location and literacy to promote changes towards more sustainable food practices within domestic environments?*

Fridge Pal provides a range of features, purposed to assist users with managing their groceries and planning their next meal (Figure 16). The application has several defining features that enable the user to (i) create and manage shopping lists; (ii) add food items manually using a barcode scanner or from previous shopping lists; (iii) view and manage food items added to the inventory and divided into fridge, freezer and pantry storage categories, and; (iv) search recipes utilising food added to the inventory. Push notifications can be used to alert users of products close to expiry. Fridge Pal was used to investigate how the app's features might help improve food supply knowledge and the level of food literacy of users.

Figure - 16 Illustrates several key interfaces of Fridge Pal.

LeftoverSwap connects those who share food with those who take shared food (Figure 17). Users are provided with a local map, and shared items are presented as pins. Users take a photo of surplus food and provide a description before sharing the item at their current location. Users can also instant message the sharer of a food item. LeftoverSwap is used to examine how food sharing can reduce food waste within a known community, as well as helping to facilitate social engagement between people.

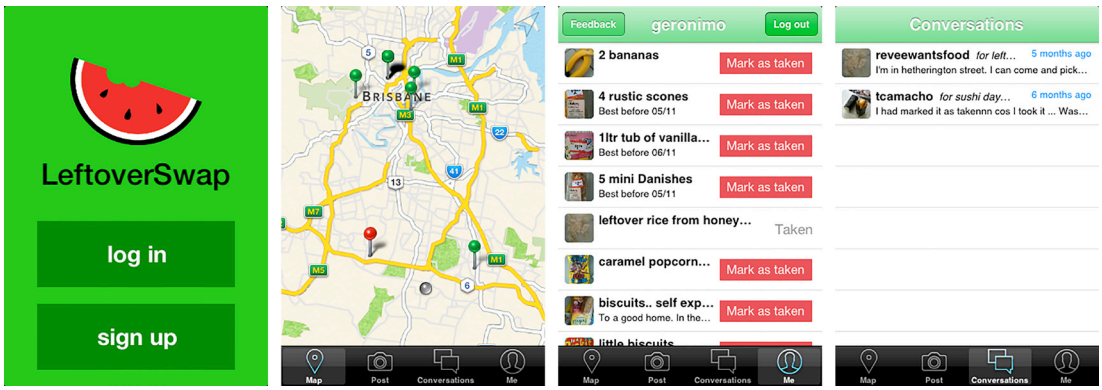


Figure - 17 Illustrates several key interfaces of LeftoverSwap.

EatChaFood encourages users to consume their food prior to expiration by providing features to assist people with managing their food, including adding food items to an inventory, viewing all food in an inventory categorised by food types, and searching recipes containing inventory items. This app extends Fridge Pal's functionality in three ways. Firstly, it provides photos of a user's fridge interior in addition to a list of available inventory items. Secondly, it provides users with a colour code scheme to improve systematic storage within their fridge. Users customise the colours representing foods on their fridge shelving, similar to Research Activity 1: The Colour Code Project. Thirdly, a shared space named 'Fridgescope' provides users with the opportunity to share food with other users. EatChaFood also provides passive notifications of food expiry by categorising food: (i) green – 5 or

more days left; (ii) yellow – 2 to 4 days left, and; (iii) red – less than 2 days left. The app was used to investigate its effectiveness in providing users with improved knowledge of what and where food items are available in storage. EatChaFood was also used to investigate how the recipe and food sharing features were utilised and if these had implications for food literacy.

Fridge Pal was used to explore how the app influences the user's knowledge about food supply, location and literacy within their household. LeftoverSwap was used to explore food sharing within a known community. EatChaFood incorporates features from both apps in order to explore the effectiveness of a single application.

3.10.2 Data Collection and Analysis

The research question was addressed by observing the use of each application over three-week periods. We conducted interviews with participants at the conclusion of each observation period. Participants were recruited from respondents to a Facebook and email advert and were screened by consideration of their age, sex, living and working arrangements, and household type. We again chose to limit our sample sizes approximately to recommended sample sizes (Nielsen & Molich, 1990): (i) 4 Fridge Pal, (ii) 7 LeftoverSwap, and (iii) 4 EatChaFood participants. Three participants used more than one of these applications. Participant attrition was quite high in our study, particularly among females; hence, participants consisted predominately of males. During each observation period, we gauged participants' use of the application of their choice once a week by questioning their thoughts regarding the application's useability and usefulness. On conclusion of each period, we asked participants a series of open-ended questions regarding four facets: (i) how the app influenced their daily practices around food; (ii) the impact the app had in reducing food waste, including informing food supply, location and literacy; (iii) the usability and usefulness of the app; (iv) the impact the app had on participants' lifestyles. Table 6 presents the participants' key details.

Research Activity 6: Participant Summary

No.	Sex	More than 1 App	Living and Working Arrangements
Fridge Pal			
F1	M	No	Shared household, PhD Student (Full-Time)
F2	M	No	Shared household, Lecturer (Full-Time)
F3	F	No	Family Household (parents and siblings), University Student (Full-Time)

F4	M	Yes (EatChaFood)	Family Household (partner and child), Stay At Home Parent (Full-Time)
EatChaFood			
E1	M	Yes (LeftoverSwap)	Shared Household, Masters Student (Full-Time)
E2	M	Yes (LeftoverSwap)	Shared Household, PhD Student (Full-Time)
E3	M	Yes (Fridge Pal)	Family Household (partner and child), Stay At Home Parent (Full-Time)
E4	M	No	Family Household (partner and two children), Entrepreneur (Full-Time)
LeftoverSwap			
L1	M	Yes (EatChaFood)	Shared household, Masters Student (Full-Time)
L2	M	No	Shared household, PhD Student (Full-Time)
L3	M	No	Shared household, PhD Student (Full-Time)
L4	M	No	Shared household, PhD Student (Full-Time)
L5	M	Yes (EatChaFood)	Shared household, PhD Student (Full-Time)
L6	M	No	Couple Household, Lecturer (Full-Time)
L7	F	No	Family Household, PhD Student (Full-Time)

Table - 6 Presents the relevant details of participants who used each of the three applications.

Fridge Pal participants were asked to utilise the app's full functionality; we provided $10 iTunes gift cards to purchase the full version of Fridge Pal. This was a necessary step, because the full version allows for an unlimited number of items to be entered into the inventory and access to additional functionalities whereas the free version is limited to only three food items.

We invited colleagues from our research lab to share food through LeftoverSwap. All lab members were acquainted with one another and consisted of a total of 17 colleagues, of which, 7 people actively shared or took food. We provided a 'shared shelf' within the lab's communal fridge that was accessible by participants. LeftoverSwap was used to notify others that food had been shared. We also provided an A4 sheet of paper and a pen on the front of the fridge for participants to place their name and the item they were either sharing or taking, because LeftoverSwap does not make clear who takes the food items offered. We used the information provided on the piece of paper to observe the sharing of food between participants. We asked participants to place shared items on the provided fridge shelf. Participants could engage in communication with the food sharer via LeftoverSwap's instant messaging feature to learn further details of the shared food item. We sent participants daily emails indicating new available food items and older items still available. We moderated the shared shelf daily, ensuring expired items were removed. A series of open-ended questions differing from the other observation

periods were asked of those who actively participated in the LeftoverSwap exercise. Questions related to three facets: (i) Food sharing in general regarding the circumstances that participants would either share or take food; (ii) Mechanisms that supported food sharing, such as LeftoverSwap; (iii) Future mechanisms and requirements to support food sharing.

To begin the EatChaFood observation, we instructed participants in the use of the app including use and maintenance of the colour code scheme, taking fridge interior photos, adding and removing food inventory items, finding recipes, and use of the shared space Fridgescope. We provided support to participants when necessary. We added an additional question to the standard open-ended questions regarding how participants used Fridgescope and what they thought about food sharing.

3.11 SUMMARY OF CHAPTER THREE

The object of this chapter was to present the methodological approach used to address the research inquiry of this thesis. This chapter has been used to present the individual research activities and the methods of data collection and analysis have been presented to demonstrate the research approach used by this thesis to investigate and inform the two research questions. Specifically, six research activities were described, to be discussed in turn in six publications that follow. The first two research activities are used in conjunction to directly investigate RQ1. The remaining four research activities are used in conjunction to investigate RQ2.

The outcomes of the research approach detailed in this chapter and the individual research activities described are presented in the following two chapters: Chapter 4: Why Do Consumers Waste Food (in answer to RQ1), and Chapter 5: Interventions to Inform Consumers (in answer to RQ2).

Chapter 4: Why Do Consumers Waste Food

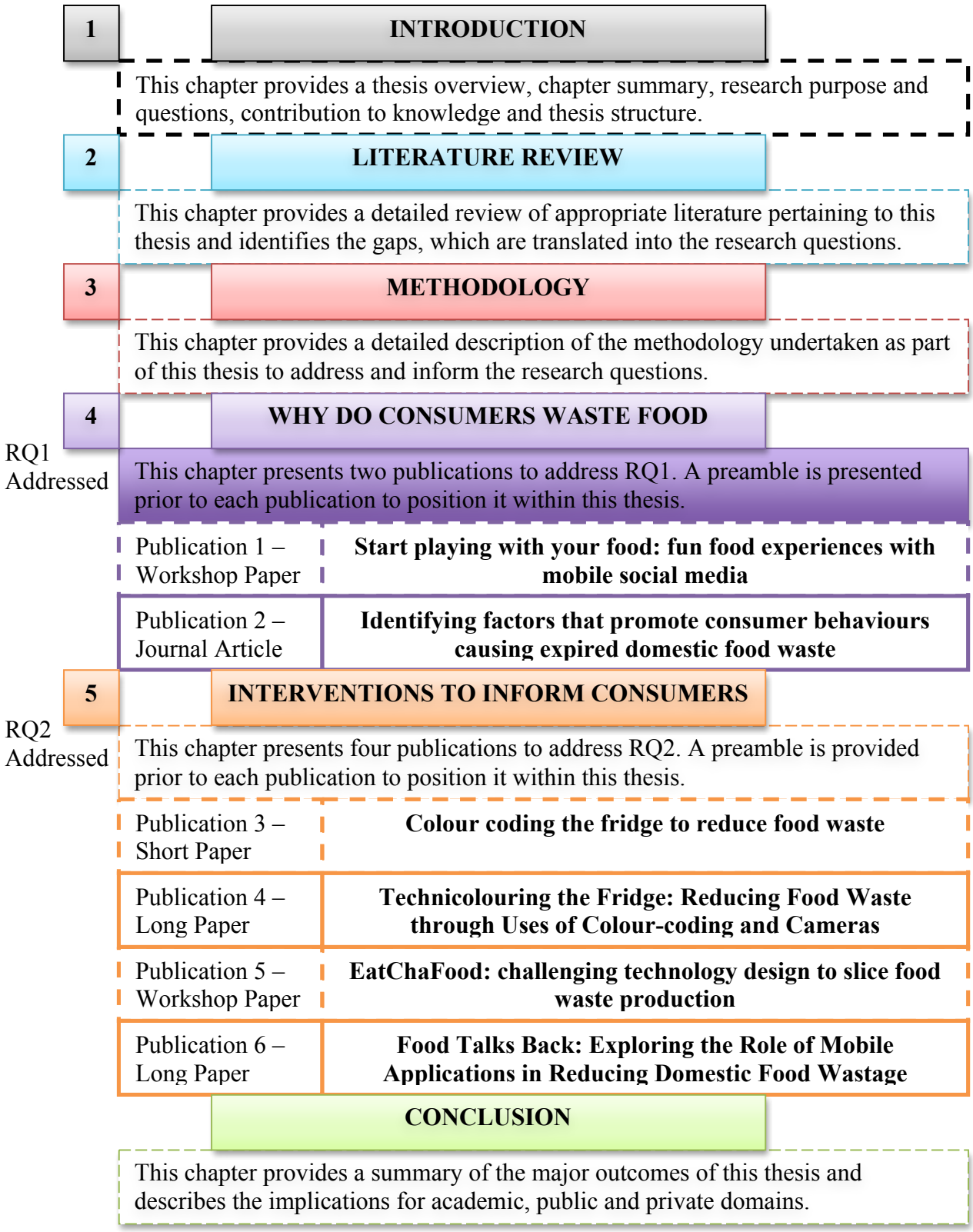


Figure - 18 A visual representation of the thesis structure with a focus on the current Chapter.

This chapter comprises two publications used in conjunction to investigate and inform RQ1. Each publication details a research activity used to investigate RQ1.

The methods of data collection and analysis associated with each research activity are described in Chapter 3: Methodology. However, the goal of the combination of these two research activities was to identify factors promoting consumer behaviours that result in domestic food waste.

The first research activity was used as a pilot study to provide clarification and insight into important variables that might be most appropriate to measure for the future research activities investigating RQ1. The research activity, I8DAT, engaged individuals through a web-based shared visual ethnographic diary. This research activity is detailed in the first publication of this thesis, entitled: *Start playing with your food: fun food experiences with mobile social media*. A description of how this publication is situated within this thesis is provided in the preamble to the publication.

The second research activity was used to identify why consumers waste domestic food. The findings from the I8DAT research activity guided and informed the direction of this research activity. The research activity comprised two main complementing data collection methods: (i) a CIP (*convergent interview process)*, and (ii) EIO *(ethnographically inspired participant observations)*. The outcomes of the CIP provided key themes, which were translated into identified factors promoting consumer behaviours leading to domestic food waste. The outcomes of the EIO confirmed the identified factors that promote consumer behaviours leading to food waste. This research activity is detailed in the second publication, entitled: *Identifying Factors that Promote Consumer Behaviours Causing Expired Domestic Food Waste*.

The research activities detailed in these two publications and used to investigate and inform RQ1 identified three major factors promoting consumer behaviours that resulted in domestic food waste.

Two further minor factors were linked to promoting behaviours that resulted in domestic food waste.

The following sections detail the findings identified in the two publications.

4.1 RESEARCH ACTIVITY 1: I8DAT – PILOT STUDY (PUBLICATION 1)

4.1.1 Overview

Figure - 19 Illustrates the publication described in this section of the chapter.

4.1.2 Publication Details

Foth, M., Choi, J. H., Lyle, P., & Farr-Wharton, G. (2011, Aug 30 - Sep 2). Start playing with your food: Fun food experiences with mobile social media. In Workshop Proceedings of Please Enjoy! Studying Playful Experiences with Mobile Technologies, MobileHCI 2011, Stockholm, Sweden. http://eprints.qut.edu.au/43743/

4.1.3 Preamble

I8DAT was developed as a tool to leverage social media in order to facilitate the sharing of information about an individual's eating experiences. Specifically, I8DAT engaged individuals through a web-based visual ethnographic diary. The website encouraged users to share information about the meals they consumed by providing a description of their meal and three associated photos: (i) the meal preparation, (ii) the cooked meal, and (iii) the aftermath / leftovers of the meal. Users were encouraged to comment on other users meals to improve user understanding of cooking, such as recipe sharing or alternative recipes to suit dietary requirements (for example, gluten free, sugar free and lactose free).

I8DAT was a tool developed and deployed as part of a larger ARC Linkage program of research. The tool was originally purposed to observe the practices of everyday people when interacting with food. The PhD Candidate's involvement with I8DAT was the major contribution to the planning, design and development (including programming) of the I8DAT website, and the collection of data once I8DAT was deployed. I8DAT was deployed in two separate locations, including South-East Queensland, Australia, and Lincoln, UK. However, the PhD Candidate

was involved with the data collection undertaken in Australia. Therefore, the findings used as part of this thesis are from that data collected in Australia only.

I8DAT is position within this thesis as a tool that provided initial insights into fundamental variables that were thought to be most appropriate to examine in the future research activities undertaken as part of this thesis to address the research questions. Specifically, I8DAT was used as a pilot study to provide clarification and insight into important variables that might be most appropriate to measure in the investigation of RQ1, such as (i) Demographics, such as age and gender, (ii) Purchasing patterns, such as frequency, quantity purchased and where food is purchased, (iii) Household income, (iv) Food interactions, such as how often food is consumed, when, where and with whom, and (v) Food waste patterns and management of participants, such as the quantity waste and types of food wasted. Further, an emphasis was placed particularly on the demographics, purchasing patterns, household income, food interactions, and food waste patterns and management during the analysis of the findings from I8DAT. This was undertaken in order to highlight the importance of these variables. Initially, these variables were thought to be most adequate for providing information that would support and guide the research direction of successive research activities used in the investigation of RQ1. The I8DAT research activity also assisted in the process of narrowing the research design of the thesis, to ensure it aligned with achievable research goals. While I8DAT had a broader goal and research question associated with the larger ARC Linkage, the question this thesis sought to draw conclusions from by using I8DAT was: *How is food waste characterised in domestic settings?*

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Statement of Contribution of Co-Authors for Thesis by Published Paper

The following is the format for the required declaration provided at the start of any thesis chapter which includes a co-authored publication.

The authors listed below have certified* that:

1. they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
4. potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit, and
5. they agree to the use of the publication in the student's thesis and its publication on the QUT ePrints database consistent with any limitations set by publisher requirements.

In the case of this chapter:

Publication title and date of publication or status:

Start playing with your food: fun food experiences with mobile social media, 2011

Contributor	Statement of contribution*
Marcus Foth	Editorial Leadership, contributed to manuscript
Jaz Choi	Contributed to manuscript, aided experimental design, design, data collection and data analysis.
Peter Lyle	Contributed to manuscript, aided experimental design, design, data collection and data analysis.
Geremy Farr-Wharton	Contributed to manuscript, focusing specifically on the 'Fun Food Diaries with Mobile Social Media' section. Also, aided experimental design, design, data collection and data analysis.
26/11/2013	

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

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07/11/2014 — Date

Start Playing with Your Food: Fun Food Experiences with Mobile Social Media

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Abstract
Healthy and sustainable food is gaining more attention from consumers, industry, and researchers. Yet many approaches to date are limited to information dissemination, advertisement or education. We have embarked on a three year collaborative research project (2011 – 2013) to explore urban food practices – eating, cooking, growing food – to support the well-being of people and the environment. Our overall goal is to employ a user-centred interaction design research approach to inform the development of entertaining, real-time, mobile and networked applications, engaging playful feedback to build motivation. Our aspiration for this study is to deliver usable and useful mobile and situated interaction prototypes that employ individual and group strategies to foster food cultures that provide new pathways to produce, share and enjoy food that is green, healthy, and fun.

Keywords
Urban informatics, food, eating, cooking, growing, mobile interaction, mobile social media, play, playful experiences, sustainability, urban agriculture, health, green HCI, fun

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Experimentation, Human Factors

Introduction

Many interactions with food create a culture of imagining, producing, preparing, and consuming food – a 'food culture' of the community at a collective level. Conversely, food culture influences behaviours of both the community and the individual. Accordingly, changing individuals' dispositions to food in day-to-day life towards more sustainable values presents opportunities for bringing about improvements in the sustainability of food cultures at a broader level. Food is a particularly challenging issue in urban contexts in which everyday food interaction for many citizens simply involve consuming ready-made meals and processed food. The problem continues to intensify with the unprecedented scale of urban growth in recent years. Now over half of the global population is living in urban areas. The UN Population Fund [23] predicts that the urban population will grow further to reach 60% of the entire global population by 2030.

Eat, Cook, Grow: Ubiquitous Technology for Sustainable Food Culture in the City is a three year collaborative research grant funded by the Australian Research Council's Linkage scheme (http://www.urbaninformatics.net/projects/ food). Our aim is to research, design and develop digital media and ubiquitous technologies as an experiment in cultivating sustainable food cultures in urban environments. Our main research locale is Brisbane, Australia, with additional reference work carried out in three cities with divergent geographic, socio-cultural, and technological backgrounds: Seoul, South Korea, for its global leadership in ubiquitous technology; Lincoln, UK, for the regional and peri-urban dimension it provides, and Portland, Oregon, U.S., for its international standing as a hub of the sustainable food movement. Brisbane will be the core site with the other cities acting as reference and reflection sites. Our team brings together experts in urban informatics, cultural studies, media and communication, and human-computer interaction (HCI) with a strong focus on sustainability to deliver actionable knowledge about the ways ubiquitous technology can make a significant contribution to creating a sustainable food culture.

With its experimental pragmatic focus, the study seeks ways to utilise ubiquitous technology's flexibility in scale of application (for example, on the continuum of individual / collective, private / public, and local / global) to improve the social, health and environmental bottom-lines of everyday human-food interaction. Put simply, we aim to contribute to better eating, cooking, and growing food in urban contexts through the use of ubiquitous technology. The specific aims of our study:

1. Examine the context of urban food culture as perceived and experienced by citizens, and analyse social, cultural, and technological challenges for active participation in sustainable food culture.
2. Explore playful interactions with both mobile and situated technologies that motivate food practices that are healthy, environmentally friendly, and fun.
3. Utilising social networking, context awareness, and locative media; design, develop and trial digital applications that encourage and support

> sustainable practices of eating, cooking, and growing food based on both personal and collective desires and needs.

The study employs user-centred design methods such as interviews, visual diaries, personas, and scenarios, to better understand contemporary shopping, cooking, and eating habits. Typologies of different food practices will inform iterative cycles of agile design and development to build and test entertaining, real-time, mobile, and networked applications that engage playful feedback to sustain user motivation. These prototypes will employ individual and group strategies to raise awareness and share knowledge in order to support the well-being of people and the environment. Our vision is to utilise ubiquitous technology in a way to engender a culture that supports people in producing, sharing, and enjoying food that is green, healthy, and fun.

Why Food and HCI?

The study seeks to identify, test, and build on technical opportunities that can be amplified, augmented, and realised to cultivate sustainable food culture for people's health and well-being in urban environments. As evident in many grassroots initiatives such as the *Local Food Movement* [collaborative effort to build more locally based, self-reliant food economies – cf. 11] and *Slow Food International* [non-profit group focusing on preservation of the cultural, culinary, and artistic local traditions – cf. 16], significant transformations arise from large-scale consensual participation of individuals identifying with the value of a sustainable lifestyle both conceptually and pragmatically.

Motivating citizens to think and act with sustainable values starts at an individual level, according to the context of the individual, *in situ*, and at the moment of concern. This is particularly significant as we make decisions about food many times a day, everyday. Effective persuasion does not easily happen through 'control and punishment' – e.g., legal systems or policy recommendations that may not be in accordance with the user's own beliefs [3, 4] – but rather by providing 'attractiveness and support' for the user to think and act in a way that is more sustainable than their current practices. The effectiveness of persuasion is increased by lowering the user's defensive levels, and this approach relies on social and playful interactions. Play theories confirm that humans are innately playful and that playful activities engage them in a fundamentally voluntary manner [cf. 5, 15]. Play thus evokes greater user motivation to interact with an application by continually presenting new opportunities for pleasurable experience and transformation [cf. 9, 22]. This study builds on Choi's PhD findings about the power of contemporary forms of urban play as an essential process of transformation for the self and the city as a technosocial network [6]. We aim to find ethical and tactical methods to influence and sustain food practices with playful interactive features that will persuade users to continuously grow into a better-informed and more active participant in shaping a food culture that is more ecological, healthy and fun. In doing so, we will take advantage of the scale-making capabilities of social networking engines to enable users to align their actions with other individuals who share similar beliefs and goals.

Recently HCI researchers have begun to examine the opportunities to use information and communication technology to promote sustainability and consciousness in environment and health on the part of technology users. Such efforts build upon and extend recent

explorations of the use of computers as persuasive technologies [12], yet the majority of studies remained within specific disciplines – environment [cf. 2, 8], health [cf. 7, 20, 21], and social [cf. 19] – despite the innate interconnection amongst them. Newly emerging movements such as *Take a Bite Out of Climate Change* (www.takeabite.cc) highlight the confluence of sustainability domains.

Simply providing people with environmental data and educational information – via mass media such as print and TV, or micro communications such as sensor networks – does not necessarily trigger sufficient motivation for behavioural change towards an ongoing health- and earth-friendly lifestyle. We want to develop a better understanding about how to go beyond just informing and into motivating and encouraging positive changes in action and perception. The study's research and development will continue and advance the research trajectory of persuasive technology and motivational design [1, 10, 12, 17]. Our focus on the locally specific contexts of Brisbane, Seoul, Lincoln, and Portland, as well as the ideological impetus to enhance societal values, will allow us to study the role of the self as an active agent for change and participant in civic activities – or 'live democracy' [18] – for sustainability through playful and fun techno-social interactions. Maintaining a food practice that upholds health, environmental, and social ideals is a demanding full-time job. It currently requires an advanced understanding of a variety of sometimes conflicting information sources and a determination to commit the necessary time and effort to always know where to buy nutrition-rich produce from local markets, according to seasonality, that is diverse and caters for differing tastes and lifestyle needs.

Research Approach

Our approach is guided by action research cycles [14] that allow us to examine context; explore playful interaction with technology, and design and evaluate applications. This process is applied to each of three different domains of food culture, which we label here 'Eat,' 'Cook,' and 'Grow.' We define eating as the direct interaction with food including purchasing produce; cooking as a process of combining ingredients to a new form to be eaten; and growing as a process of producing and harvesting food.

	2011	**2012**	**2013**
EAT	**Focus**	**Iteration**	**Iteration**
COOK	Context	**Focus**	**Iteration**
GROW	Context	Context	**Focus**

Fun Food Diaries with Mobile Social Media

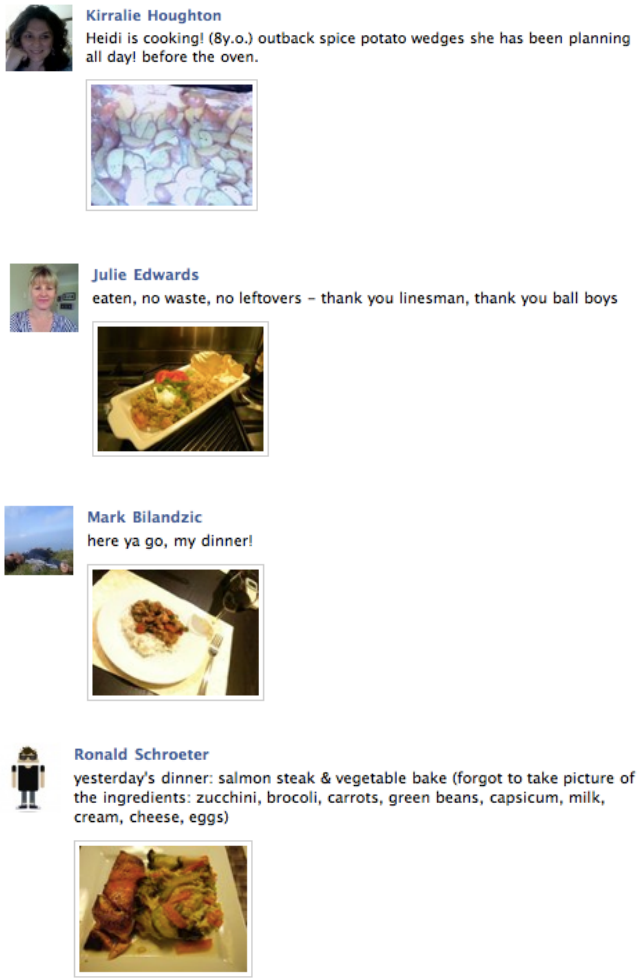
We are in the process of experimenting with employign mobile social media to create visual food diaries. They are private or semi-public blog entries detailing the food that our study participants eat – including meals and snacks – consisting of a snapshot of the food and personal notes such as whether the food is ready-made, price, and their reflection. In Goffman's [13] discussion of gender disparities in visual advertisements, he notes how en massed images depict the overarching message that may be concealed in individual photographs. Similarly, diaries are used to elicit common themes from the participants' shared

food culture by analysing the pool of all collected photographs while personal notes function as complementary descriptive data. For the participants, this allows them to reflect on their eating habits. Our aim is to examine and raise awareness of the current contexts that influence individual dispositions towards and practices of eating, then analyse social, cultural, and technological challenges for active participation in creating sustainable eating culture.

In the "Please Enjoy! Studying playful experiences with mobile technologies" workshop at MobileHCI 2011, we want to showcase and discuss our research study and the *I8Dat* (pronounced 'I ate that') mobile social media prototype application. We asked our initial pool of internal test users to upload photographs of each meal they eat over a two-day period of their choice, capturing the following three stages:

1. The ingredients and/or preparation area;
2. The prepared uneaten meal – depending on how many people the dish was prepared for, this may be a photo of the table with the meal laid out and prepared;
3. The leftovers and/or scraps – includes any food waste, scraps or food from the meal or meal preparation that was not consumed.

Early results follow – more to be shown at the workshop ☺



Jan Seeburger
Ok I'm happy that I can show off my Hokkaido Soup Curry here :-D

Ingredients for Soup:
chicken stock, carrot, celery stick, onions, apple, tomatoes, chunk dark chocolate, bay leaf, 5 large cloves garlic, ginger, dried chili pepper, cumin, turmeric, coriander, black pepper corn, garam masala, curry powder, oil, salt/pepper

Soup Toppings:
Carrot, Chicken, Green beans, lotus root, mushrooms, eggplant, broccoli

Absolutely delicious...

Conclusion

We employ a critical design approach for developing and deploying technologies, followed by design criticism that takes place at the end of each action research cycle. Evaluation from design criticism is subsequently integrated into the next cycle. The underlying design concept is based on the play theory developed by Choi [6]: playful interaction allows the user to be aware of sustainability issues germane to the current context, help them find ways to overcome problems, pursue positive actions, and share the experience in ways that are pleasurable to them.

Acknowledgements

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4.2 RESEARCH ACTIVITY 2: CIP AND EIO (PUBLICATION 2)

4.2.1 Overview

Figure - 20 Illustrates the publication described in this section of the chapter.

4.2.2 Publication Details

Farr-Wharton, G., Foth, M., & Choi, J. H. (2014, online first). Identifying Factors that Promote Consumer Behaviours Causing Expired Domestic Food Waste. Journal of Consumer Behaviour. http://eprints.qut.edu.au/70482/

4.2.3 Preamble

It was identified in Chapter 2: Literature Review and reiterated in Chapter 3: Methodology that interventions targeting behaviour change have often been met with varying success. Commentators suggest that this is because of the complex and challenging nature of changing consumer behaviours and that maintaining changed behaviours overtime is even more challenging. Instead of exploring a similar approach to behaviour change, this thesis aimed to encourage behaviour change by firstly, identifying the factors that promote consumer behaviours resulting in domestic food waste and secondly, investigating interventions that target the identified factors, thereby encouraging more sustainable domestic food practices. The publication documented in this section (Publication 2) was positioned in this thesis to describe the research activity used to identify the factors promoting consumer behaviours resulting in food waste and therefore, informed RQ1.

The research activity denotes two main data collection methods used to address RQ1: a convergent interview process (CIP) and ethnographically inspired participant observations (EIO). The CIP was used to investigate grocery shopping practices and experiences, food storage practices, household cooking habits, food waste management practices, and food waste prevalence. The method undertaken to achieve this has been described in Chapter 3: Methodology. The outcomes of the CIP

yielded key themes, which were then translated into identified factors promoting consumer behaviours leading to domestic food waste. These identified factors were investigated through EIO. The outcomes of the EIO consequently confirmed the identified factors that promote consumer behaviours leading to food waste. These factors could then be targeted by interventions described in the publications succeeding the current chapter.

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Statement of Contribution of Co-Authors for Thesis by Published Paper

The following is the format for the required declaration provided at the start of any thesis chapter which includes a co-authored publication.

The authors listed below have certified* that:

1. they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
4. potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit, and
5. they agree to the use of the publication in the student's thesis and its publication on the QUT ePrints database consistent with any limitations set by publisher requirements.

In the case of this chapter:

Publication title and date of publication or status:
Identifying Factors that Promote Consumer Behaviours Causing Expired Domestic Food Waste, 2014

Contributor	Statement of contribution*
Geremy Farr-Wharton	Wrote manuscript, developed experimental design, conducted experiment and data analysis,
26/11/2013	
Marcus Foth	Contributed to manuscript, aided experimental design
Jaz Choi	Contributed to manuscript, aided experimental design

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

MARCUS FOTH — Name

Signature

07/4/2014 — Date

4.3 CHAPTER 4 SUMMARY

This chapter presented two publications that were used in conjunction to investigate and inform RQ1. The pilot study I8DAT was the first research activity used to begin the investigation of RQ1. The activity's motive was to ascertain how food waste is characterised in domestic settings. The outcomes of the activity identified useful variables to examine for the succeeding research activity. The research activity is described in the first publication forming this chapter (Publication 1). The second research activity used two main methods of data collection: a CIP and EIO. The motive of the activity was to inform RQ1 by firstly, identifying key themes that translated into identified factors promoting behaviours resulting in domestic food waste. The outcomes of the study identified three major factors promoting behaviours and two minor factors, which in turn addressed RQ1. Identifying these factors allows for interventions to target them to encourage more sustainable domestic food practices, which are explored in Chapter 5: Interventions to inform consumers.

Chapter 5: Interventions to Inform Consumers

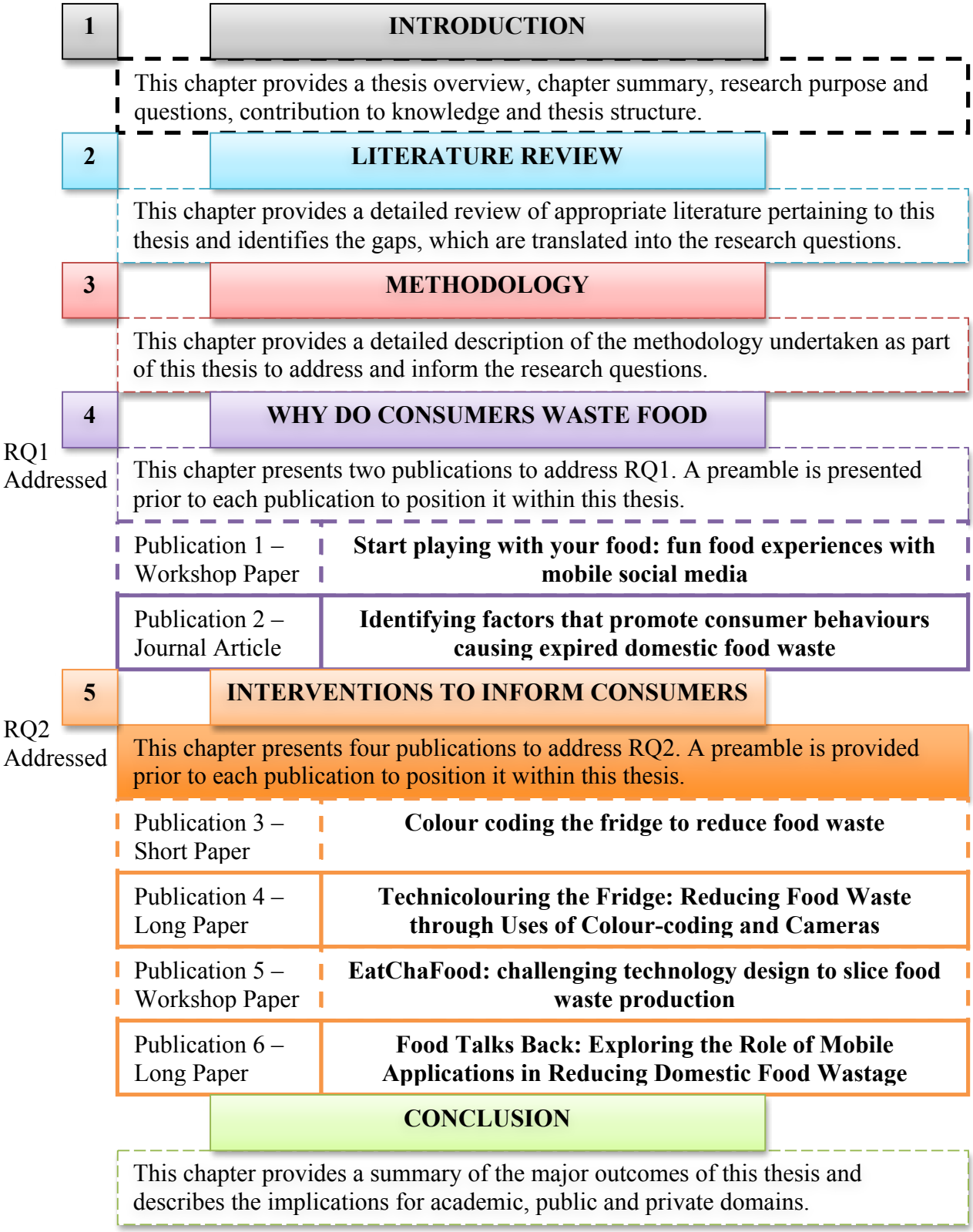

Figure - 21 A visual representation of the thesis structure with a focus on the current Chapter.

5.1 RESEARCH ACTIVITY 3: THE COLOUR CODE PROJECT (PUBLICATION 3)

5.1.1 Overview

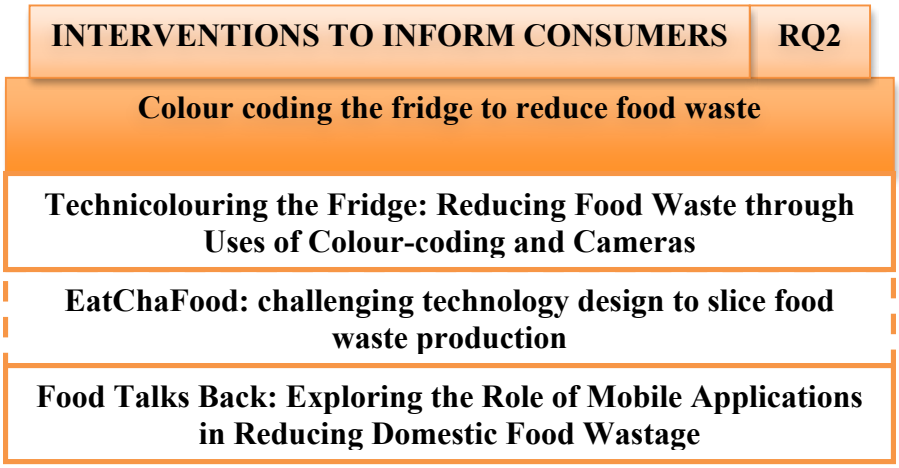

Figure - 22 Illustrates the publication described in this section of the chapter.

5.1.2 Publication Details

Farr-Wharton, G., Foth, M., & Choi, J. H. (2012, Nov 26-30). Colour coding the fridge to reduce food waste. In Proceedings of OZCHI 2012 (pp. 119-122), Melbourne, VIC. New York, NY: ACM. http://eprints.qut.edu.au/54184/

5.1.3 Preamble

The Colour Code Project, the first intervention employed as part of this thesis, was used to target a factor identified in the investigation of RQ1: current household food location knowledge. The intervention targeted the household fridge and involved the application of a colour scheme to different locations on fridge shelves to indicate where particular types of food could be located or placed. The intervention was used to examine the effectiveness of a colour scheme to improve a user's food location knowledge, in order to reduce domestic food waste. Specifically, the intervention aimed to inform a sub-question of RQ2: *Does the organisation of a colour scheme for different food types in a household refrigerator raise the awareness of available foods for all members in the household and does this consequently lead to a reduction in expired food waste?*

The Colour Code Project provided an opportunity to explore this question to investigate if such a system of food storage may assist people in managing their food supply more effectively than if no system of food storage was employed. Specifically, examining the effectiveness of a system of food storage could help to

make foods items visible and draw focus to particular locations within the fridge. A colour code map placed on the front of the fridge provided users with an indication before opening the fridge of where to expect items to be located. This reduced the risk of items being forgotten or lost towards the back of the fridge, even if the items had reduced visibility.

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Statement of Contribution of Co-Authors for Thesis by Published Paper

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The authors listed below have certified* that:

1. they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
2. they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
4. potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit, and
5. they agree to the use of the publication in the student's thesis and its publication on the QUT ePrints database consistent with any limitations set by publisher requirements.

In the case of this chapter:

Publication title and date of publication or status:
Colour coding the fridge to reduce food waste, 2012

Contributor	Statement of contribution*
Geremy Farr-Wharton	Wrote manuscript, developed experimental design, conducted experiment and data analysis,
26/11/2013	
Marcus Foth	Contributed to manuscript, aided experimental design
Jaz Choi	Contributed to manuscript, aided experimental design

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

MARCUS FOTH — Name
Signature
07/11/2014 — Date

Colour Coding the Fridge to Reduce Food Waste

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ABSTRACT
This paper introduces the first iteration of a study aimed at grouping similar food types together in a refrigerator to increase the awareness of available foods for consumers in a domestic environment. The goals of the project are twofold: i) Raise the awareness of available foods for all members of a household; ii) Reduce the amount of expired food waste in the household. The project implemented a paper-based colour scheme in refrigerators in households, assigning colours to particular food types (e.g. green to fruit and vegetables, red to meat, etc.). The findings show that the colour coding raised participants' awareness of available food items in the fridge, particularly for those participants who were not directly involved in the shopping and initial storage of each food item. The findings also indicate that such awareness led to a reduction in expiration of food and thus general food waste in the household. These preliminary findings suggest that raising awareness of food availability through categorisation and efficient communication of this information may lead to a reduction in food waste in domestic environments.

Author Keywords
Food waste, consumer behaviour, colour coding, human-computer interaction, domestic technologies, urban informatics.

ACM Classification Keywords
H5.m. Information interfaces and presentation; Human-centered computing → Field studies; Empirical studies in HCI; Empirical studies in interaction design;

INTRODUCTION
Currently in Australia alone, households throw away over AU$5 billion worth of food annually, and this represents approximately 40% of total household rubbish (excluding recyclables and garden waste) (Catchlove, 2010). This has, in some cases, severe repercussions for the environment in the form of both a greenhouse effect and land real-estate occupation (Wang, Odle III, Eleazer and Bariaz, 1997). Additionally, Schneider (2008) argues that on average, globally, around 25% of the available food supply is wasted. These wastages happen along the supply chain with a significant portion of the losses occurring in the household and food retail outlets (Kantor, Lipton, Manchester and Oliveira, 1997; Schneider, 2008). Specifically in households, Kantor et al. (1997) found that the majority of the waste comprised food that had been forgotten and expired in the refrigerator or pantry. This is a growing problem that needs to be addressed.

OZCHI'12, November 26–30, 2012, Melbourne, Victoria, Australia.

An additional issue governing much of the consumers' behaviour when purchasing food is the conceptual disconnect from food production. Industrial commodification has led to food being more affordable than it used to be in the past. Especially younger people are often not overly concerned about ensuring to consume all the food they have purchased before it expires, and therefore tend to readily throw out expired unconsumed goods (Hill and Lynchehaun, 2002; Padel and Foster, 2005). Further, the food that is thrown out adds to the waste accrued through the entire food supply chain. Expired food waste is prevalent in developed nations and causes significant methane gas production from rotting.

Schneider and Obersteiner (2007) suggest that the behaviour that leads to the prevention of household food waste is determined by several factors including (but not limited to): age, income, and time spent at home. In addition, situational conditions are also argued to influence particular behaviours that may lead to food waste, such as smell, appetite, desire for food and marketing or advertising of a specific product (Lebersorger, 2008; Schneider, 2008). Schneider (2008) proposes several methods of food waste prevention that can be integrated into households. They include using a shopping list, using highlighted tabulated measurements for rational food portion sizes, education in creative uses of food residues, education about the equivalent monetary value of wasted food items for a given consumer, and general food waste awareness training (Schneider, 2008). These outcomes represent opportunities to be integrated into a human-computer interaction design intervention.

There are some underlying issues with the functionalities of modern refrigerator design leading to behaviours that cause a higher risk of producing expired food waste. The issues may not be inherent to fridge design itself, but rather a combination of several factors, stemming from consumer behaviour, the perceived value of food, time-poorness in many households, as documented in a number of studies (Calderon, Iglesias, Laca, Herrero and Díaz, 2010; Levy, 2012; Schneider, 2008). The fundamental problem that the combination of these elements causes is the stockpiling storage behaviour, which causes items in the fridge to get pushed to the back and be no longer easily visible by members of the household and often to be forgotten about until a regular blitz or spring clean of the refrigerator takes place.

In addition, when any member within a household opens the fridge, they are often presented with various food types in a number of different locations. Many

households develop their own – principally tacit – system of organisation whether it be ordered or chaotic. These circumstances were identified to be a problem factor. In recent years, there have been increased discussions about how technology can be used to influence behaviour change within the domain of HCI. This paper explores such an opportunity. The following sections of this paper will present the methodology, findings to date, and discussion from a study that aims to increase the awareness of available foods for consumers in a domestic environment. The paper will conclude by looking at the limitations of the study and its potential future developments.

PRIOR RESEARCH WORK

This paper is based on a mixed-method study that was conducted as part of a three-year PhD project, which explores HCI design opportunities to reduce food waste in Australian urban households. The study promotes healthier and more environmentally sustainable food practices by promoting more efficient purchasing and storing of food, as well as general management of food waste in everyday life. As part of the project, a study was conducted to explore a person's awareness of available food within the context of a shared household (3+ people), a couple household (two people), and a family household (a couple with children). This study builds on a previous study also undertaken as part the PhD project that identified the key factors for behaviours that yield expired food waste in each of the aforementioned households. This study found three major factors and two minor factors for behaviours that result in expired food waste. The three major factors:

- ***Transparency*** (an individuals' forgetfulness or memory concerning the food they have placed in or taken out of the fridge / freezer / pantry);
- ***Awareness of available foods*** (an individuals' knowledge of food items available in the fridge / freezer / pantry for consumption);
- ***Misled / incorrect tacit knowledge*** (the tacit knowledge of an individual who knows if a product with or without an expiry date is edible or not by the use of sight, smell and / or touch).

The two minor factors include:

- ***Unplanned events*** ('spur-of-the-moment' situations that led to a cancellation of a previously planned consumption of food that was purchased for that specific meal);
- ***No desire to consume leftover food*** (a person having cooked a large meal with the intentional goal for the meal to last several consecutive mealtimes, but does not resume desire to consume the leftovers before they go off).

This study responds to the problem factor of ***awareness of available foods***. The study specifically focuses on designing an intervention within the context of the household refrigerator, because the previous study found that this location contributed to the majority of expired food waste, as compared to the pantry or freezer. This study actively engaged consumers by encouraging them to think about where they place items of food in the refrigerator by organising the different food items into clearly defined areas, where each food type is represented by specific colours.

The research premise of this study is: *Does the organisation of a colour scheme for different food types in a household refrigerator raise the awareness of available foods for all members in the household and does this consequently lead to a reduction in expired food waste.*

METHODOLOGY

Guided by a user-centred design approach, members of households were recruited to participate in this study from responses received to an online survey conducted as part of the previous study disseminated to everyday Australian grocery consumers and through the social networks of the researchers.

Seven households were recruited for this study: Four couple households, two family households with 1 and 2 children respectively, and one shared household comprising three people. Recruited members of households represented a spread across a range of demographics. Their occupations included a range of full-time roles in private and public sectors; full-time and part-time students; and full-time stay at home parents. Full-time workers represented the majority of participants and were often busy people. Our screening survey revealed that participants differed quite significantly in their shopping frequencies and the places they shopped for food (this included local food markets, IGA, Coles, Woolworths and local grocers). A small portion of the participants purchase food knowing exactly what they planned to eat the following week (until their next shop), whereas other participants would purchase 'opportunity' food that they thought they might like to eat throughout the week or what could be used in meals. Participants were located across South-East Queensland, Australia.

The study took place over a four-week period. The first two weeks were used to gauge the average quantity of expired food waste produced per week. Participants were encouraged to either write the product name and quantity in a journal or take a photo of product that they threw away to assist in this process. At the end of the second week, the colour code scheme (described below) was implemented and the study continued for a further two weeks to gain insight into how the system was used and its effectiveness in reducing food waste. All participants were asked to customise their preference for which colours would correspond to each food type.

Interview protocols and visual ethnography (Pink, 2007; Schwartz, 1989) were used as qualitative data collection methods. Informal interviews were conducted once a week at the participants' houses. Emergent themes were derived from the qualitative analysis of the interviews. Questions were directed at a household representative who was chosen by all household members. Questions related to four main areas:

- The quantity of food from the fridge, which had expired that week;

- The level of difficulty which participants' had in locating food items in the fridge;
- Had the colour code scheme influenced their shopping patterns in any way;
- Any difficulties or barriers experienced by participants' from using the colour code scheme.

At each interview, photographs were taken of the refrigerator (by the researcher). The photos were a mechanism to not only view the movement of food within the context of the refrigerator and to view participants' engagement with respect to the colour code scheme, but also corroborate what participants' were stating in their interviews. In addition, participants were encouraged to either take a photograph or write down a list of all expired products that were thrown away each week and the quantity associated with that product. This was to assist in gauging the quantity of expired food waste in order to see whether the colour code scheme provided an impact on expired food waste.

A formal debriefing interview was conducted at the end of the study, which all members of the household were involved. This interview covered the experiences of all participants involved in the study. The formal interview protocol comprised of five main questions, each intended to provide insight into: participants' thoughts and experiences with the colour-coding scheme, longer term practicality, impact on participants' awareness of food items, possibilities for technology integration, and thoughts on how intensive they found their participation.

Colour Code Scheme

The colour code scheme entailed using seven different coloured pieces of opaque plastic that were matched (by the participant) to a corresponding food type. The different food types available for a participant to select from included: *Fruit and Vegetable Produce, Dairy, Condiments, Meat, Bread/Baked Goods, Drinks, and Leftovers*. The different food types were determined by results from the aforementioned previous study that showed that participants tend to conceptualise the items in their fridge into groups similar to their grocery shopping experience. The coloured sheets of plastic were cut using common household tools and blue tack was applied to the sheets to ensure they would stick to the shelves of the fridge for the duration of the project. Refer to Figure 1 that illustrates the colour code scheme applied to one participating households' refrigerator.

Figure 1. The Colour Code Scheme applied.

Finally, a 'map' was drawn up of the configuration and printed on an A4 sheet of paper, then stuck to the front of the fridge. This was so any member about to open the fridge door would know in which direction to look for the food type they were after. Participants were asked to customise the colour scheme and change the colour scheme as they saw fit over two weeks. Figure 2 shows an example of the map of the colour code scheme applied in Figure 1.

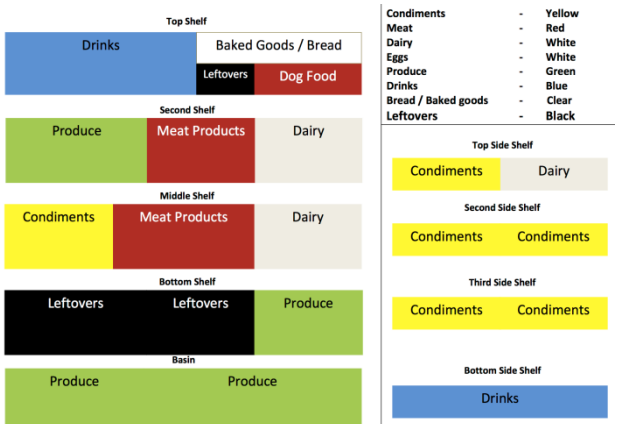

Figure 2. A colour coded map of the interior of an example refrigerator.

RESULTS AND DISCUSSION

Key themes were derived from the preliminary findings of this study which are now discussed in turn.

The Colours of Food

An unexpected finding from the study showed how participants link particular colours to certain food types. Although participants were given the option to choose the colours that they felt best corresponded to food types, they assigned the same colours to the same food types: Green for Produce, white for Dairy, yellow for Condiments, red for Meat, clear for Bread/Baked Goods, blue for Drinks, and black for Leftovers. This assignment of colours to food types might represent a recognisable choice for many. However, a deeper analysis might reveal linkages between contemporary food marketing and people's perception of colours in relation to food types. Given that this study employed a relatively small sample pool, this theme needs further exploration.

Impact on the Awareness of Available Food

The main dilemma currently leading to expired food wastage in households is that not all household members have knowledge of available consumables in their fridge at a given moment. This is because, within a household, there would generally be a primary purchaser of food who often solely arranged the food for storage. This realisation came from the informal interviews that were conducted with participants and cross referenced with findings from a previous study. The lack of food interaction during the purchasing or storage of groceries prevented other household members to gain actionable knowledge of foods available in the fridge. This can also be applied to members who may not reside in the household and instead, who may visit and still require use of the refrigerator. They would be able to see the 'map' enabled by the colour code scheme on the front of the fridge and

generally know where to look for particular items of food when the fridge door was opened.

Weekly interviews revealed that the colour coding had led to a significant increase in participants' awareness of the foods they had available in their refrigerators. This was more so the case with family households or couple households who both held full-time positions. However, all households showed a noticeable increase in awareness. Several participants mentioned this was because of two underlying factors. The presence of the colour schemes required participants to frequently look at the colour-map because the memory of what colour corresponded to what food type dissipated the less frequently used a colour code was. This process continually refreshed their memories about the location of food types in their fridge. Once participants became used to the colour code scheme, they no longer used the map.

The second factor mentioned by participants was that the colour code scheme helped them find items of food more quickly than usual. In addition, the participants in turn suggested this reduces their overall effort to retrieve food. One participant said, "This process works. I've only thrown away one lemon this week." In comparison to their previous weeks (without the intervention) expired food waste had noticeably fallen. The difference in the amount of food waste varied amongst participants, but on average, each household cut their expired food waste production by at least a quarter to a half of what they had previously produced. These initial findings will need to be cross examined and with the final debriefing interview protocols and the photographs taken through the use of the visual ethnography measurements to explore the significance of these factors and to either confirm or disprove them.

Effectiveness in Reducing Expired Food Waste

This study's intention was to promote reduction of expired food waste by increasing the awareness of available foods for everyone residing in the household in question. The preliminary findings indicate that because there has been an increase (a significant increase in some households) of available foods in the fridge of a household, participants became more conscious of the food they could eat. Moreover, they became more conscious of when particular foods would expire than before the colour code scheme was implemented. The preliminary findings showed that participants were consuming more of the food they had purchased and became more active in their pursuit to minimise the amount of food that would expire in the fridge. The informal interviews provided insight into the different motivations for such pursuits. Several participants mentioned that the study itself caused them to become more conscious of their actions, while others mentioned monetary, social, and environmental motivations. Overall, the preliminary findings suggest that use of the colour code system leads to a reduction in expired food waste. Further exploration and analysis are required in order to obtain the extent of the impact the Colour Code Project has in raising the awareness of available foods for all members of a household and in return reducing the amount of expired food waste in the household for a significant period beyond their participation in the study.

CONCLUSION

This paper has presented the preliminary findings of the first iteration of the Colour Code Project. The findings suggest that using the colour code scheme in the refrigerator reduces the amount of expired food waste in households by increasing the awareness of available foods in the refrigerator for all members in a household. Further research is required to explore the additional and longitudinal impact of the colour code scheme – for example, running it in larger households to see if the children of a household are able to effectively adopt the colour code scheme, despite the height disparity. The next step in this research is to understand the interactions that people have not only with the colour code scheme, but with other household members (including interactions grounded by social and cultural norms). Understanding these interactions will shed insight into the human-computer interaction requirements that are needed to be imbedded within the design of current household or personal technologies in order to better facilitate a change in people's behaviours within the household that will lead to a reduction in expired food.

ACKNOWLEDGEMENTS

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5.2 RESEARCH ACTIVITY 4: FRIDGECAM (PUBLICATION 4)

5.2.1 Overview

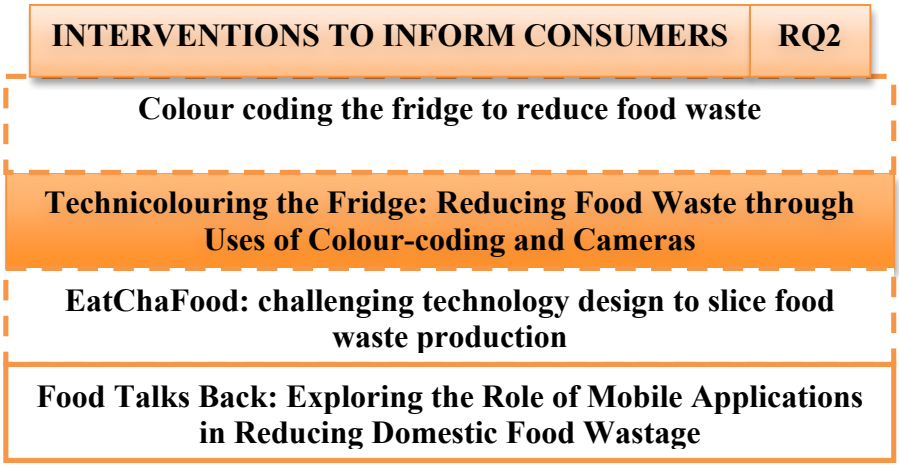

Figure - 23 Illustrates the publication described in this section of the chapter.

5.2.2 Publication Details

Farr-Wharton, G., Choi, J. H., & Foth, M. (2014, Nov 25-28, in press). Technicolouring the Fridge: Reducing Food Waste through Uses of Colour-coding and Cameras. Submitted to 13th International Conference on Mobile and Ubiquitous Multimedia (MUM), Melbourne, VIC. http://eprints.qut.edu.au/77532/

5.2.3 Preamble

FridgeCam, the second intervention employed as part of this thesis, was used to target a factor identified in the investigation of RQ1: current household food supply knowledge. FridgeCam was positioned within a fridge's interior to take regular photos of the fridge's state every three seconds the door remained open. The photos were automatically uploaded to a specific web address for users to utilise during their shopping experiences. FridgeCam was originally used as a technology probe to reveal more about everyday domestic food practices (Ganglbauer et al., 2013). FridgeCam is used as part of this thesis to examine how such an intervention can be used to improve an individual's knowledge of their available food supply.

FridgeCam provided an effective and previously tested mechanism to target the improvement of a user's food supply knowledge. The intervention further gave the opportunity to gain an initial insight into a comparison between improving an individual's food supply knowledge and food location knowledge to reduce domestic food waste. The comparison was made possible by using the findings from the first

intervention, the Colour Code Project, and the findings of FridgeCam. Therefore, the investigation of this comparison resulted in the sub-question of RQ2: *How can situated interventions targeting the domestic fridge provide users with improved food supply and location awareness to encourage changes towards sustainable food practices?*

The publication described in this section investigates the use of the Colour Code Project and FridgeCam within domestic environments to examine the effectiveness of these interventions to improve food supply and location knowledge and encourage sustainable food practices. The outcomes of the two research activities provided key features and concepts that could be incorporated into a mobile application, which would be explored as part of this thesis.

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The following is the format for the required declaration provided at the start of any thesis chapter which includes a co-authored publication.

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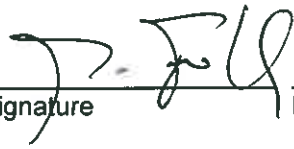
Technicolouring the Fridge: Reducing Food Waste through Uses of Colour-coding and Cameras, 2014

Contributor	Statement of contribution*
Geremy Farr-Wharton	Wrote manuscript, developed experimental design, conducted experiment and data analysis, developed tools used to collect data.
26/11/2013	
Jaz Choi	Contributed to manuscript, aided experimental design
Marcus Foth	Contributed to manuscript, aided experimental design

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

MARCUS FOTH — Name

 — Signature

07/11/2014 — Date

Technicolouring the Fridge: Reducing Food Waste through Uses of Colour-coding and Cameras

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ABSTRACT

Domestic food wastage is a growing problem for the environment and food security. Some causes of domestic food wastes are attributed to a consumer's behaviours during food purchasing, storage and consumption, such as: excessive food purchases and stockpiling in storage. Recent efforts in human-computer interaction research have examined ways of influencing consumer behaviour. The outcomes have led to a number of interventions that assist users with performing everyday tasks. The Internet Fridge is an example of such an intervention. However, new pioneering technologies frequently confront barriers that restrict their future impact in the market place, which has prompted investigations into the effectiveness of behaviour changing interventions used to encourage more sustainable practices. In this paper, we investigate and compare the effectiveness of two interventions that encourage behaviour change: FridgeCam and the Colour Code Project. We use FridgeCam to examine how improving a consumer's food supply knowledge can reduce food stockpiling. We use the Colour Code Project to examine how improving consumer awareness of food location can encourage consumption of forgotten foods. We explore opportunities to integrate these interventions into commercially available technologies, such as the Internet Fridge, to: (i) increase the technology's benefit and value to users, and (ii) promote reduced domestic food wastage. We conclude that interventions improving consumer food supply and location knowledge can promote behaviours that reduce domestic food waste over a longer term. The implications of this research present new opportunities for existing and future technologies to play a key role in reducing domestic food waste.

Categories and Subject Descriptors

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Experimentation, Human Factors.

Keywords

HCI, behaviour change, user behaviour, colour code, FridgePal, food supply, food location, urban informatics, Australia

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1. INTRODUCTION

An increasing amount of global food waste is contributing to environmental problems, exhaustion of landfill capacities and has implications that jeopardises global food security. Each year, Schneider [28] argues that 25% of the global edible food supply is discarded, which has a severe impact on maintaining food security. Further, the discarded food produces greenhouse gas emissions that impact the environment and tightens free land development to house landfill estates, instead of housing, industry or other developments [36]. Schneider and Obersteiner [29] suggest two-thirds of domestic food waste can be prevented, arguing that a person's behaviours are the leading drivers of domestic food waste. They suggest several indicators that can influence waste prevention behaviours, including: age, income and time spent at home. Situational conditions can also promote food waste. They include: smell, appetite, desire for food and marketing/advertising of products [21, 28].

Recently, research into human-computer interaction (HCI) sought to encourage behavioural changes, so as to achieve environmental sustainability [10]. This presents an opportunity to examine the role of HCI to either encouraging or discouraging people to change their behaviours and in turn, impact food waste. In addition, a number of recent interventions have aimed to assist users with their everyday tasks. An example of such an intervention is the Internet Fridge (also known as the Smart Fridge). The aim of numerous iterations of the Internet Fridge was to provide Internet and multimedia access to benefit users. This was facilitated through a visual display located on the front of the fridge door. The display provided a number of features that enabled users to: (i) browse the Internet, (ii) manage household appliances remotely, such as air conditioners, and (iii) manage a limited range of their food supply stocks through sensory information to automatically re-order food items and thereby reduce the shopping burden of users [7]. The Internet Fridge is example of a technology that has failed to saturate the market. There were various reasons for the downfall of the Internet Fridge. However, it is widely accepted that the technology's benefits were ambiguous to users, particularly when compared to the benefits of the common household refrigerator [16, 23]. The high costs associated with purchasing the Internet Fridge further deterred users from purchasing the technology and contributed to the perception of an unnecessary commodity. This outcome provides opportunities to investigate interventions that may help overcome the shortcomings of innovations, such as the Internet Fridge and thereby provide increased benefits to users.

A growing number of interventions co-locate themselves with a refrigerator to provide key information regarding a user's food storage activities. In this paper, we examine two such interventions: FridgeCam and the Colour Code project. We

investigate each intervention's ability to assist users with managing their food in domestic settings. Both interventions are situated within the household fridge; each providing an intimate view of the user's interactions with their food over a period of time. This examination differs from previous attempts by addressing issues such as food supply and location knowledge, and visibility. Our study provides insights for future interventions about the features that may improve user knowledge of their food supply and how these features may be used to reduce domestic food wastage.

2. LITERATURE REVIEW

Food wastes are identified by one of four states: (i) original food, (ii) partly consumed/used food, (iii) leftovers (plate waste), (iv) preparation residues (off cuts, fat from meat, egg shells, vegetable and fruit peels) [28, 29]. In many cultures, novel ways to reuse food wastes are often explored, particularly through traditional methods of cooking, livestock feeds and fertilisers [35]. There are a number of causes of food waste. However, causes of domestic food waste predominately occur during food purchasing and once food enters the home [20]. Specifically, in their study of Australian households, Farr-Wharton, Choi and Foth [11] argue a lack of food supply and location knowledge are key factors promoting domestic food waste practices during food purchasing and storage. Specifically, Farr-Wharton, Choi and Foth [11] argue a lack of food supply and location knowledge are key factors promoting domestic food waste practices during food purchasing and storage.

Food overproduction in industrialised nations is met with marketing ploys utilised by the food industry, which are passed on to consumers and designed to impact their purchasing decisions [8, 9, 33]. For example, consumers are encouraged to make bulk purchases, because it is often cheaper than buying the same quantity of the single product [19]. However, it is not always practical for a person to consume the bulk amount within the timeframe of purchase and expiry. A product will often be discarded and replaced with fresher produce when it reaches expiry and the impacts of discarding the product may not be considered Marketing strategies are a key tool used by the food industry to reduce food waste. However, as a result, the wastes can then occur in domestic settings instead, particularly when consumers bulk purchase products. To assist consumers with managing bulk purchases, systematic food storage practices become crucial [11]. Farr-Wharton, Choi and Foth [11] argue systematic storage can assist consumers to locate food and reduce the impact of domestic food waste practices, such as food stockpiling. This presents opportunities to assist consumers with systematic food storage in domestic settings to reduce food waste.

Further, a combination of peoples' behaviours during food purchasing, storage and consumption, and a variety of different conditions of a person's lifestyle can lead to domestic food wastage practices. Robinson and Smith [26] indicate a person's attitudes, beliefs and subjective norms impact their food practices more than their age and gender [31, 33]. Food price, quality and brand familiarity also bare weight on a person's purchasing decisions, which are reflected in their purchasing practices [6, 37]. However, purchasing practices are also influenced by a person's food supply knowledge [11]. If consumers are informed that products are already available in storage during food purchasing, it may prevent purchases of the same product. This presents opportunities to creatively provide key information to consumer of their available foods supply during food purchasing.

The purpose of household fridges is to store and prolong the life of food through cooling. This core design and functionality has an inherent flaw; the increased storage space promotes food stockpiling practices. Food can often be pushed to the back of shelves where it is no longer visible, which can make it easier for food items to be forgotten. Products are left to expire, only to be found when the fridge is cleaned. Fridges were obviously not designed to encourage this behaviour. However, modern refrigerator design relies on fridge users to know their available food supply and location of food items. These factors can be cumbersome for people with time-poor lifestyles and the low value place on food further reduces the incentive to do so [cf. 5, 22, 28]. Additionally, occupants in households with two or more members can be unaware of available food and its location, which may have been purchased by others. This presents an opportunity to provide household members with improved awareness of the household food supply and the food's location.

Spangenberg and Lorek [32] argue behaviours can be hard to predict and influence; and Schneider [28] contends that all preventative measures for food waste should take a long term perspective that encompasses both a comprehensive and integrated approach. This suggests that solutions supporting behaviour change would benefit from targeting causes of behaviours instead of addressing the behaviours themselves. This could provide a mechanism for sustained long-term behaviour change. To reduce domestic food waste, such an intervention could target the household fridge, because it is a tool that can impact both food purchasing and storage. Emerging studies in HCI have targeted behaviour change, enabling both the recognition of climate change [38] and methods for pursuing a more environmentally sustainable lifestyle for individuals and society [13]. Blevis [2] and Fogg [14] further position HCI as a key tool to assist a behaviour change process. Previous studies have explored the effectiveness of several motivational techniques such as rewards, emotional motivation, intrinsic motivation, gamification, and goal setting. However, maintaining changed behaviours over time has proven difficult [1]. This is often because individuals experience an initial interest and motivation to change and overtime, the interest dissipates because of lifestyle, time availability and other external factors [18]. Further, Blevis [2] argues HCI research must consider embedding interaction and engagement into technology to stimulate a behaviour change process. This consideration has been approached using four complementary mandates:

a) Provide people with knowledge and awareness of their consumption practices as to encourage a change towards more sustainable practices [10].
b) Target the integration of persuasive techniques and methods into technology to assist individuals to adopt sustainable practices with tasks and activities undertaken in their everyday life [17, 34].
c) An approach that combines the preceding two perspectives in order to instigate a change towards more sustainable consumer practices.
d) Rather than changing individual behaviours, HCI interventions could also aim to change the environments we live in through an activist approach [4, 15]. The successes and failures of HCI behaviour change studies have varied with many studies gaining initial interest and stimulated behaviour changes, but failed to maintain those behaviours over time. An example is the polar bear experiment [10]. The [virtual] polar bear motivated users to decrease energy consumption. It encouraged

reduced energy consumption through engaging user emotions by changing the bear's state depending on energy consumption. The bear would appear happy and playful when consumption was low and sad when consumption was high. Dillahunt et al. [10] documented the challenges of maintaining behaviour change. Participants' feedback stated that over time the bear would be turned off or ignore. Reasons given indicate it was repetitive and participants' felt as though they could not do anything about their energy consumption, which was impacting the bear.

HCI interventions targeting behaviour change face several challenges. Firstly, Brynjarsdottir et al. [3] argues persuasive technology needs to be tailoristic in its approach and that consideration of a person's environment be examined, because behaviours are enacted within certain contexts. Secondly, managing the complexities of maintaining long-term behaviour change is challenging [1]. This provides opportunities to investigate the effectiveness of using interventions to influence the causes of behaviours, thereby encouraging a behaviour change response.

Following this line of enquiry, our study explores two pilot studies, each involving a HCI intervention and exploring how each may be used to increase the benefits to users and overcome the shortcomings of previously failed interventions, such as the Internet Fridge. Firstly, we investigate FridgeCam and its influence in raising a user's awareness of their food supply. Secondly, we examine the Colour Code Project and how food location can be improved to reduce food waste. These interventions are guided by the research question: *How can situated interventions targeting the domestic fridge provide users with improved food supply and location awareness to encourage changes towards sustainable food practices?* We chose not to investigate the third factor identified by Farr-Wharton, Choi and Foth [11] in this study, because of the complex nature associated with understanding food and challenges of improving a user's food literacy. However, we explore this factor in our future research.

3. RESEARCH DESIGN

FridgeCam was originally used as a technology probe to reveal more about everyday domestic food practices [15]. In our study, we used FridgeCam (Study 1) to improve an individual's knowledge of their domestic food supply. We used the Colour Code Project (Study 2) to improve an individual's knowledge of the location of food. For each study, we recruited participants from our social and professional networks. While recruits had a familiarity with the researchers, we ensured study candidates underwent a screening process that noted household type, income and number of household residents before being selected to participate. We excluded candidates if the number of residents within their household was less than two. We did this to specifically examine couple, shared and family households. Further, smaller sample sizes comprising between 3 and 5 participating design evaluators are identified to be more effective than larger groups in providing useful design evaluations [24]. Therefore, we elected to limit the sample sizes based on Nielsen and Molich [24] recommended sample sizes.

Each intervention was implemented over four consecutive weeks accompanied by observations and brief interviews with a designated household representative, selected by the household. We encouraged participants to provide comments and feedback of their intervention usage during the brief interviews. We conducted a final interview on conclusion of each study and asked each participant opened-ended questions regarding their intervention usage. Thematical analysis was applied to evaluate the interview data. We applied visual ethnographic techniques [25, 30] to better understand the movement of food observed in the FridgeCam photographs. We also encouraged participants to take photographs when they felt a photo might show a significant occurrence, determined by them. In both cases, interviews were thought to be the best mechanism to provide a rich understanding of the impact of each study to raise food supply or location awareness. We later cross-examined the interview responses with associated photographs to corroborate what was said.

3.1 The Interventions

3.1.1 Study 1: FridgeCam

FridgeCam is an application installed on an Android device and secured to the inside of a fridge door to take several photos of a fridge interior each time the door is opened. Photos were made available to household occupants at a specified web address (mobile accessible). On visiting the address, occupants were provided with the 15 most recent photos uploaded by FridgeCam. In Study 1, the device was installed the first week of commencement. Study 1's photographs were used to ascertain the management of refrigerated food and the time spent searching for items. The final interviews with FridgeCam participants addressed four areas: (i) the influence photos had on shopping practices, (ii) the impact to participants' food supply awareness, (iii) the participant's perceived impact on food waste, and (iv) the different locations photos were utilised and the barriers to using them. We recruited 7 households in total (equalling 10 individuals) to use FridgeCam Study 1 (see Table 1). 3 of the households (a total of 6 individuals) discontinued the study after the first week of implementation for reasons, including: technology issues and conflicts of interest. However, 4 remained until the study completed. Three of the four households involved in the FridgeCam study also participated in the Colour Code Project two months prior to the FridgeCam study commencing. However, we ensured all materials from the Colour Code Project were no longer in use by those who commenced using FridgeCam to ensure equal conditions for all participants.

Table 2. A depiction of each household involved in Study 2: The Colour Code Project

#	Household Type	Living Arrangements	Number of Occupants in Household	Occupations of Residents in household	Household Income	Shopping Practices (per week)
F1	Unit	Shared household	Two	Full-time workers (9pm-5pm)	$80,000 per annum	One large shop
F2	House	Family household	Three (including a child)	Full-time worker (9pm-5pm) & stay-at-home parent	$70,000 per annum	One large shop and several top-up shops
F3	House	Couple household	Two	Full-time workers (9pm-5pm)	$90,000 per annum	Several small top-up shops
F4	Unit	Shared household	Three (a couple and a house mate)	PhD student & 2 full-time workers (9pm-5pm)	$110,000 per annum	Several small top-up shops

Table 2. A depiction of each household involved in Study 2: The Colour Code Project

#	Household Type	Living Arrangements	Number of Occupants in Household	Occupations of Residents in household	Household Income	Shopping Practices (per week)
C1	House	Family household	Three (including a child)	Full-time worker & stay-at-home parent	$70,000 per annum	One large shop and several top-up shops
C2	House	Family household	Four (including two children)	Full-time workers	$150,000 per annum	One large shop
C3	Apartment	Couple household	Two	PhD student & full-time worker	$80,000 per annum	One large shop
C4	House	Couple household	Two	PhD student & full-time worker	$50,000 per annum	Several top-up shops
C5	Apartment	Couple household	Two	Full-time workers	$120,000 per annum	One large shop
C6	Unit	Couple household	Two	PhD student & full-time student	$60,000 per annum	Several small top-up shops
C7	Unit	Shared household	Three (a couple and a house mate)	PhD student & 2 full-time workers	$110,000 per annum	Several small top-up shops

3.1.2 Study 2: The Colour Code Project

The Colour Code Project implemented a paper-based colour scheme positioned within the household fridge. Each colour represents a food group encouraging only food items of a particular group (such as produce) to be placed on the corresponding colour (e.g. green). We encouraged households to continue customising the colour scheme once it had been installed. Figure 1 shows a before and after photo of C1's fridge interior with and without their customised colour scheme implemented. A colour scheme 'map' was provided on the front of the fridge door for quick reference, which was updated if colour changes occurred and can be viewed in Figure 2. A total of 7 households (equalling 18 individuals) participated in Study 2 (see Table 2). We used the initial two weeks of commencement to observe the quantity of domestic expired waste of each household by taking note of the number of expired products and what they were. Additionally, we performed an evaluation of the most appropriate placing of colours during this period. We encouraged participants detail discarded expired products into a provided journal, which contained: (i) the product name, (ii) quantity, and (iii) a photo. We requested participants to store waste in a bin we provided to assist our observations. We disposed of the bins contents on a weekly basis. The colour code scheme was implemented at the beginning of the third week and remained until the conclusion of the study.

Figure 1. An illustration of C1's fridge interior before and after the colour scheme was applied.

We used Study 2 to examine how the scheme was used and its effectiveness in both raising awareness of food location and its influence in reducing expired food waste. During weekly visits to participant's households, we asked a nominated household representative a number of questions that concentrated on: (i) the participants' perceived impact on food waste, (ii) participants' levels of difficulty in locating food items, (iii) the perceived impact on shopping patterns, and (iv) the challenges participant's experienced. During the visits, we captured photos of the household fridge and bin provided to observe: (i) the changes in food placement within the fridge, and (ii) what food was discarded because it reached expiration. Further, the photos presented an opportunity to understand how participants engaged and interacted with the colour code scheme; with a particular focus on the challenges participants faced both personally and socially (with other household members). We asked a series of open-ended questions at the conclusion of Study 2, which focused on five themes: (i) participants' experiences, (ii) the potential uses of the colour code scheme over a longer time, (iii) the time participants took locating desired food items, (iv) ideation of opportunities for technology integration and finally, (v) impact on participant's everyday domestic lives.

4. Findings

The interviews and photographs from each study provided insight into four characterising themes, which extend upon outcomes of a previous study [12]. The key themes include: (i) the impact on user knowledge, (ii) the social implications, and (iii) design enhancements. These themes provide a deeper insight into how technologies can be used to better promote behaviour change and reduce domestic food waste. On concluding the findings, we also present an observation regarding those participants who were involved in using both FridgeCam and the colour code scheme.

4.1 The Influence On User Awareness

Each intervention's impact on a user's food supply or location awareness was the major theme emerging from the interview analysis from Study 1 and 2. Firstly, F1 and F2 representatives from Study 1 stated that visual images provided assistance in "helping [them] remember" what items they had in the fridge. F3 suggested this was particularly useful with items such as milk, cheese, meat and leftovers, which were suggested as the most frequently used items. However, all Study 1 participants raised a limitation with FridgeCam photos. In all cases, the inadequacy of visibility regarding all available products was highlighted as a limitation for the participants. F2 further stated "I could see that I had milk and butter, but I couldn't see how much I had left inside each or if they had expired", highlighting another limitation regarding the visibility of items. F3 stated "if I had the ability to

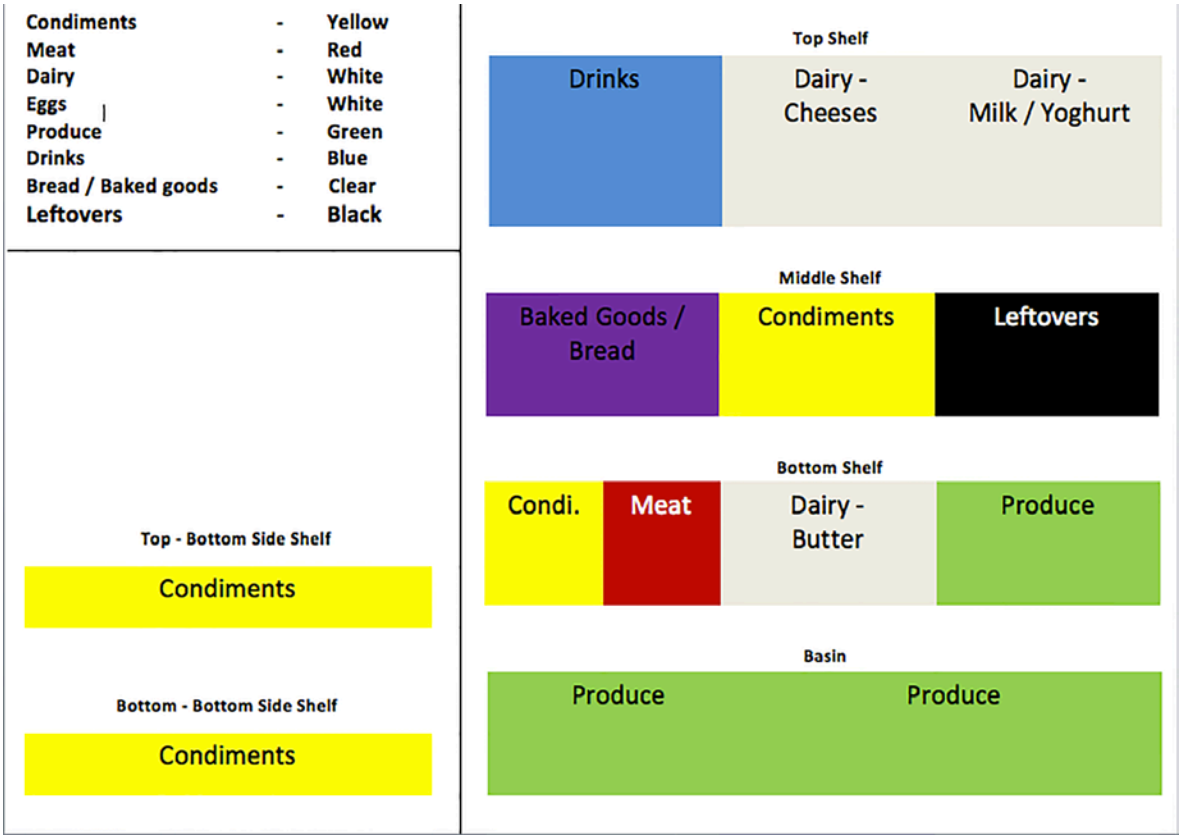

Figure 2. An illustration of C1's colour scheme 'map'.

adjust and move FridgeCam with ease, I might have gotten a better angle that showed me more items".

Figure 3 shows examples of each household fridge regarding what can and cannot be seen with the FridgeCam and where the device is located. F3 also stated that unless there were multiple cameras, each with differing angles of view; it was unlikely that FridgeCam was able to provide them with information about all available food in their fridge. F3 further stated, "while I don't think FridgeCam can provide this, if it was able to, I would quite happily change some of my practices" (such as opening the fridge to see what products are available before going to the supermarket to purchase groceries). Additionally, F2 stated that on several occasions "I looked at the FridgeCam photos and noticed I already had some products that I intended to buy, so I didn't end up buying them and I would have without the photos". F2 further stated that they perceived a reduction in their expired household food waste, which they believed FridgeCam photos influenced. An observation made by the researchers of F2's household waste corroborated the statement given by F2. A similar outcome was identified for the F1 and F3 households. However, F4 viewed the FridgeCam photos sparingly and no change in expired household food waste was observed.

Similarly, Study 2 showed an influence on food location awareness. All participants in Study 2 stated that they experienced a perceived increase in knowing where to find food items in their fridge. Several comments in the interviews suggested that the colour scheme map placed on the front of the fridge assisted with knowing where to locate items before participants opened the fridge door. However, on further inquiry, all Study 2 households stated that they stopped using the colour scheme maps after the first few days because they knew [roughly] the general location of items. The findings indicate that the visual colour scheme supported knowledge growth about item location. However, C2, C5 and C6 stated their preference for actual pictures of food to be printed on the coloured plastic pieces to show what items can be placed on a colour, which would make the map redundant. In future research, we suggest that pictures of meat, dairy and produce, etc. be placed on the appropriate colours for better recognisability.

Further, our Study 2 findings indicated that in comparison, food waste after each week was less for those participants using the colour code scheme, rather than those who used the FridgeCam photos. One explanation for this finding is that increasing awareness of item location is more effective in decreasing waste compared with increasing knowledge about the available food supply. However, because these are pilot studies, more testing and evaluation is required. Our findings also indicated that households could maximise their food waste reducing through the use of a system of food storage, such as the colour code scheme. Study 2's C1 and C4 stated that the colour scheme had a significant influence on reducing expired waste in their homes. They suggested this was because of the de-cluttering process and the implementation of a system of storage undertaken when implementing the colour scheme within the fridge. Their photographs taken of their fridge interior support this hypothesis. Therefore, this positions the implementation of a system of food storage in a household as an important mechanism to assist with reducing expired household food waste. On the other hand, an observation of the photos taken of the household fridge in C3 and C7 throughout the experiment indicated that approximately 30-40 essential food items were commonly stored. For this reason, both

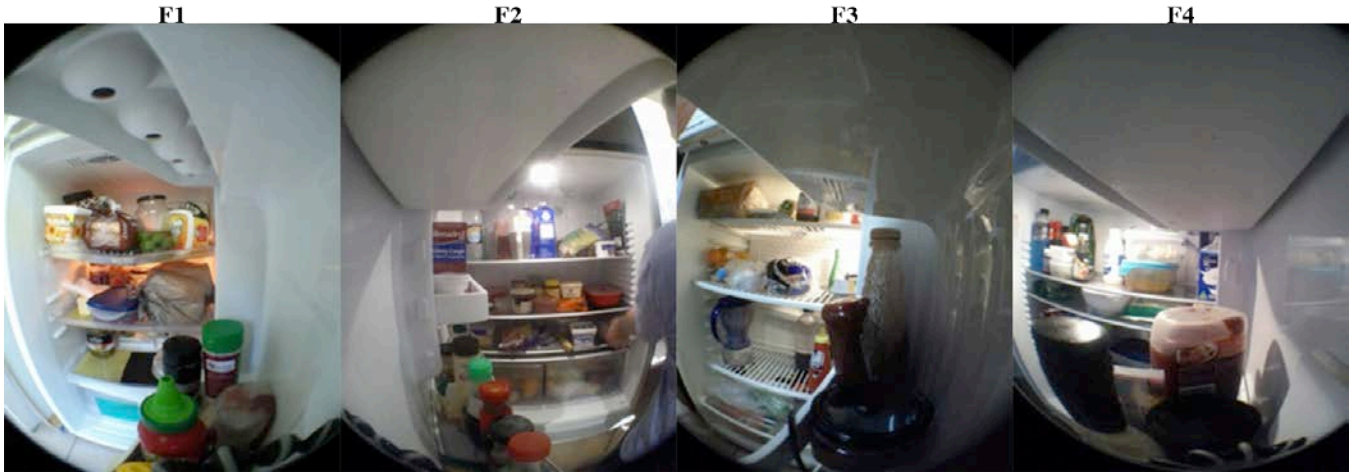

Figure 3. A Demonstration of example FridgeCam photos taken of each participating household's fridges.

representatives suggested that a system of storage, such as the colour code scheme, was not needed. The fridge interior of C3 can be viewed in Figure 4.

4.2 The Social Implications

Privacy and security concerns continually surfaced in FridgeCam Interviews and concentrated on a theme regarding social implications. The concern was not centred on what others may think of the household fridge's appearance, but what the FridgeCam photos might reveal about household members to a wider audience. F1 and F2 representatives expressed their concern that the wide-angle lens of FridgeCamp can capture a person while they are retrieving items. That photo is then uploaded onto the web at a 'read-only' address, preventing the deletion of any photos (a limitation of FridgeCam). Participants felt 'out of control' because of this and were concerned photos might reveal private and potentially embarrassing images. F1 and F2 representatives both concluded that if FridgeCam provided the ability to have "control" over the photos that were uploaded; the scope of the image would have been reduced.

Additionally, a theme regarding social impacts surfaced during the Colour Code Project interviews, noting that on occasion, household members (generally family members) would express anger and frustration towards fellow household members. The interviews showed that the majority of households experienced [minor] conflict as a result of members placing food items in "wrong" storage locations. If a household member recognises that another member has clearly placed an item in a wrong location (purposefully or not), frustration and anger towards the other member was experienced. Household representatives suggested the item would then usually be relocated to the correct colour. This became particularly evident with responses from C1, C2, C4 and C6 representatives, each stating the household liked the control and ordered nature the colour scheme provided. C1 and C6 representatives further stated their willingness to continue a similar order and categorisation of food types in their fridge once the study had concluded. The majority of households expressed a like for the colour code scheme because it enabled a level of fridge storage control over other household members and an ability to ensure particular items are always found in a known location.

Both studies contextualises the challenges inherent to implementing HCI interventions within domestic settings. With each intervention, a social dilemma was experienced. The photos FridgeCam took concerned participants. Not having control over exactly what content was included in FridgeCam photos and then not being able to delete or edit photos taken gave participants a fear of embarrassment, being unsure if photos could be publicly

Figure 4. A display of the fridge interior of C3 before and after the colour code scheme was implemented.

viewed. The Colour Code Project experienced another kind of social dilemma with participants who chose to opt-out of using the colour scheme being publically shamed inside the household by other members. This too may have been met with embarrassment for the person who chose to opt-out. However, other household members experienced frustration and anger because there was someone in the household who was actively choosing not to comply with a 'new' household 'culture' provided by the colour scheme. Moreover, a further theme surfaced during FridgeCam interviews regarding social impacts. All households stated their interest in showing friends and family the FridgeCam photos, as well as, the FridgeCam device itself. On further inquiry, participants were asked if they felt concern about being judged with others having the ability to view the participants' fridge (because privacy is an issue commonly spoken about in the literature). Again, privacy arose as an issue. However, participants felt that sharing information between friends was not as intrusive as they first thought on reflection and suggested that it could have further uses. However, participants were unable to specify how this might take place. These social phenomena provide a foundation to be explored in later studies.

4.3 Design Enhancements

FridgeCam participant interviews provided a final theme regarding design enhancements. Specially, the imbedding of gamification elements into FridgeCam was noted, such as task and goal setting or an awards scheme. In particular, the F1 representative stated that they personally would benefit greatly from an awards scheme style of motivation. They further suggested that having goals or tasks that encouraged them to interact more with the FridgeCam photos would have increased their desire to use FridgeCam and greatly improve its usefulness. The F2 representative further stated that reminders notifying the participant to use FridgeCam at particular moments would have helped in enabling a continued pattern of usage. The F2 representative suggested that in their household, if reminders were given for two weeks, a maintained pattern of usage would occur after that period of time. However, it would only be successful if a perceived usefulness of the technology was realised during and after that time as well.

Similarly, Colour Code Project participant interviews highlighted a theme regarding design enhancements, with participants pondering how elements of the project might be integrated with technology. Many liked the idea of having a greater control about where items were stored and the ability to find those products with ease at a later date. However, they questioned the usefulness of having the Colour Code Project available through a mobile device or on the computer. Their comments suggested that this related more too whether the participants would need that information away from their fridges and questioned whether such a technology solution should be made available through the fridge itself. Nevertheless, several participants expressed their interest for their fridge interior to be made available to them away from their fridges. This presents an opportunity to integrate other functionalities that might be required in the food purchasing phase and not just the storage phase.

Participants from both studies showed an interest to extend the functionality of each intervention, which they thought would increase its usefulness and usability. The suggestions given for each intervention may assist the shortcomings of each and may overcome the barriers to longer-term use of similar interventions in domestic settings. Further investigation might provide insight into the role that technology and the imbedding of gamification elements into interventions can have in encouraging behaviour change and subsequently, decreasing domestic food waste.

A final observation made several months after the Colour Code Project had concluded showed several participating households have either kept to the original colour scheme (with the coloured plastic sheets remaining in the fridge) or have instigated a similar re-customised arrangement of the colour code scheme. This was evident in households C1, C3 and C4, of which are still using a system of storage in the same capacity as what the Colour Code Project instigated in their households. Each of these households suggests a maintained behaviour change and a decreased waste production, continued. This shows the capacity for the Colour Code Project to instigate a maintained change of behaviour. Of those households who also participated in the FridgeCam study, the Colour Code Project was suggested to have done more to change behaviours that resulted in a greater reduction of expired household food waste than what the FridgeCam provided.

5. DISCUSSION

5.1 Raising Food Supply and Location Awareness

With several households involved in both studies, observations can be made for comparisons between each. While we did limit the sample sizes in accordance with the practices outlined by Nielsen and Molich [24], our findings showed both studies achieved their intended purpose. That is, FridgeCam provided an improvement to food supply knowledge of users and the Colour Code Project improved food location awareness. However, the comparison of themes identified in our findings suggests a larger percentage of households experienced a reduction in food wastage during their time using the colour code scheme, rather than participant's experiences using FridgeCam photos. Consequently, the findings suggest that improving food location knowledge may have a greater influence on reducing domestic food waste, than improving supply knowledge. We suggest that food location knowledge provides people with the ability to easily recall where items are most likely located, because of the colour code scheme and the person can consume an item without having to search for it. This outcome may result because of a loss of motivation to locate an item if it cannot be quickly found. Instead, another item might be chosen for consumption as a replacement, because it is easier to locate or more readily available without the need for search. On the other hand, increasing a person's knowledge of their food supply, does not necessarily translate into knowing where a food item is located. Therefore, we surmise the ability for a person to approach food storage and know where to locate foods from a particular food type, influences food waste more than knowing what food is available in the person's food inventory. However, our findings indicated that a multi-facet approach to domestic food waste reduction is needed. We surmise that a combination of improving consumer food supply and location awareness through a number of means will provide the best outcome and assist with influences practices that currently lead to food waste.

In future research we propose that consideration be given to the contextual use of each application. Firstly, the colour code scheme was present during food storage, thereby reminding participant's where to correctly store or retrieve items. However, participants have to remember to use FridgeCam photos for the visual information they provide to be useful. Therefore, future research needs to separate the impact of one intervention from the other, so that the impact of each intervention is clearer. For example, our

findings indicated that FridgeCam photos provided the opportunity for participants to view the products already in storage and thereby prevented unnecessary purchases that would lead to stockpiling practices. Farr-Wharton, Choi and Foth [11] identify interventions targeting improved food supply awareness during food purchasing as a key factor to prevent practices that lead to food waste. However, participants had to remember to view the photos prior to or during their shopping experience. If the participant did not do this, they may have continued their practices, which existed before the study.

The social aspects of life, while possibly not considered directly related to how we use technology, cannot be ignored when designing technology. Particularly with HCI and interaction design, the social dynamic is a critical component. The findings from our study reflected this. Specifically, there was an apparent display of encouragement from other participants in a household to ensure all members of the household adhered to the colour code scheme and specifically, the location items were stored in the fridge. This process likely facilitated a general shifts in behaviour towards more sustainable practices. Further, we argue the process led to intrinsic motivation for users to utilise a system of storage within their household. However, we concede that the social dynamics that may have been the motivation, which encouraged participants to use the colour code scheme and not the motivation to reduce food wastage. We suggest this outcome because participants understood that if they did not comply with the scheme, it would negatively impact other household members. Therefore, the motivation for reducing food waste may not have been present and instead, a positive secondary outcome – a comparative finding that was demonstrated by Ross & Tomlinson [27]. We make the recommendation that food supply and location knowledge are key factors that can lead to a reduction in domestic food wastage. We suggest that food supply knowledge may better inform users to assist them with their purchasing decisions during shopping experiences. We further surmise that food location knowledge is best provided to a user when they are storing or retrieving an item from storage. We make the recommendation that a technology, such as the Internet Fridge, may benefit from including storage information on a digital display co-located with storage appliances.

5.2 Implications for Behaviour Change Maintenance

Our findings indicated that participants had initial expectations about the use of each intervention, which in the majority of cases did not reflect the actual use observed during the studies. Participant's experiences using the interventions indicated that in some cases, the intervention failed to meet the user's expectations. We argue this outcome caused our participants to lose their perceived value in using the intervention and subsequently, the intervention was either no longer used or was utilised in a limited fashion. The findings indicated that at this point, our participants' behaviours returned to their original practice and unsustainable practices continued. Our findings showed that this was particularly the case with the FridgeCam intervention. This also supports Bishop [1] argument that maintaining a behaviour change overtime is challenging. Conversely, participants using the colour code scheme did not initially perceive the colour to be useful. However, our findings indicated that through social pressures or general curiosity, participants found the colour code scheme to be beneficial and changed their practices to place items in their correct locations. We further saw participants stating their preference to continue using the colour code scheme, with some changes, after the study concluded.

Our findings also showed further comments surfaced regarding the use of both interventions. However, the focus was on each intervention's customisability. Specifically, the findings showed participants wanted better ways to customise the interventions, with some participants suggesting it might improve how the intervention they were using would be utilised in the future. This supports the recommendation by Brynjarsdottir et al. (2012) for HCI design to be tailoristic and incorporate the individual needs of a person. Further, when observing this trend through a critiquing lens, customisation appears to enhance the functions and usability of an intervention through personalising it. The impact of customisation as an enabler of technology adoption, particularly with those seeking to instigate behaviour change needs further exploration. Suggestions provided during the FridgeCam study raised the integration of gamification elements into technology. HCI design incorporating gamification elements may improve the use of interventions targeting raised awareness of food supply and location knowledge. The integration of gamification into technology to serve a targeted purpose has been adamantly explored in the literature. Recently, a number of studies have explored the use of gamification in encouraging changes in energy usage, suggesting that gamification may assist a behaviour change process. Conversely, there are also very critical views of it as well. If gamification elements were integrated into one of the interventions, such as the suggestion provided by our participants to incorporate a rewards feature, the question remains, "would users continue using the intervention after the rewards are gone?"

5.3 Opportunity to Overcome Limitations of Previously Failed Technologies

It would be difficult to state particular design elements that should be integrated into technologies seeking to impact behaviour or reduce expired household food wastage. This is because the sample sizes of each study are limited and therefore, generalizability is limited. What our findings suggest is that design features that worked in one situation, did not necessarily in the other. In light of this, we argue a key assertion; a holistic approach that considers and incorporates a user's location, technologies they use, household type, household fridge size and number of housemates. A comparison between the findings from both studies indicates that if an intervention is to be implemented to encourage behaviour change; the intervention may be more successful if it is located in the same place as the change is to take place. For example, the colour code scheme was implemented within the fridge to assist users with their food location awareness at the location where food storage occurs. Therefore, we argue interventions targeting behaviour change would benefit from being co-located with the instrument where behaviours are enacted.

Further, our FridgeCam findings showed that participants often experienced a situation where they wanted key information about a product in their fridge, such as how much butter is still available for consumption. However, we saw that in our case, the technology failed to provide the necessary knowledge, because of the inherent limitations that were communicated to participants before undertaking the study, such as the placement of FridgeCam within the fridge can be prone to reduced visibility displayed in photos. To overcome some of this limitation, our findings showed participants raising suggestions such gamification or alert features, which could be integrated into FridgeCam. These

suggestions may provide added benefit to users encouraging the use of the intervention and thereby, having an impact in raising the awareness of a user's food supply. Further, integrating the intervention, such as FridgeCam, into an already existing social paradigm, such as a shared household, may also provide higher levels of adoption because of social pressures. While we saw this occur with the Colour Code Project, we recommend further investigation of this occurrence to gauge its effectiveness.

Our findings also identified that the Colour Code Project provided a new storage pattern, which was moderated socially by other household members. For example, our findings saw household members frowning upon others if they did not follow the organised storage pattern. This points to a social paradigm previously explored by [12] and provides support for interventions to consider social contexts in the design process, particularly regarding support for sustainable practices. We further postulate that, from our findings, the type of household and the lifestyles of a user plays a significant role in whether an intervention can and will be used, as well as where it will be used. We also suggest the size of the household fridge should be a consideration. This is because the size of storage can limit the quantity of products that can be purchased, or at least stored in refrigeration to prolong shelf life. These are design considerations that we recommend be considered when designing interventions that target improved user awareness of food supply and location to reduce domestic food wastage. We argue these design considerations have potential to overcome many of the limitations that have been experienced with previously failed technologies, such as the Internet Fridge. We reiterate the limitations of our own study and express the need for future research in this area to include larger sample sizes to examine the generalizability of the results. However, we suggest that our study has provided a foundation, from which future research can use to produce more effective interventions targeting support for sustainable food practices.

6. CONCLUSION

Our study investigated the use of two interventions, which target the reduction of domestic food waste by providing consumers with raised food supply and location awareness. We found that FridgeCam and the Colour Code Project can be used to reduce domestic food waste and also have the potential to overcome the limitations of previously failed technologies, such as the Internet Fridge. In our discussion of our findings, we made several recommendations to further extend upon the outcomes of this study, including implementing the interventions with larger sample sizes to better understand the generalizability of outcomes. We identify a number of recommendations for HCI practitioners to consider when designing interventions targeting improved food supply and location knowledge. We suggest the findings of this paper provide early foundations to explore how improved knowledge of food supply and location can be used to encourage more sustainable food practices and maintain behaviour change over time. Our research design can be applied to future interventions targeting similar outcomes.

7. ACKNOWLEDGEMENTS

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5.3 RESEARCH ACTIVITY 5: EATCHAFOOD (PUBLICATION 5)

5.3.1 Overview

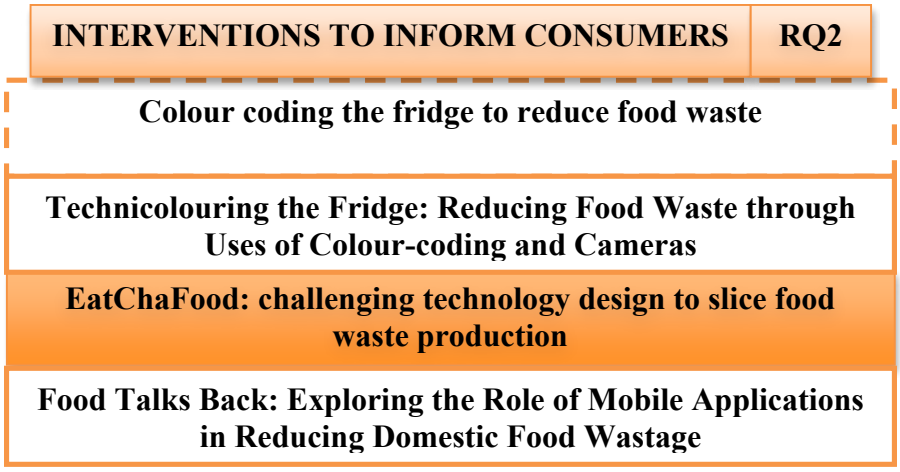

Figure - 24 Illustrates the publication described in this section of the chapter.

5.3.2 Publication Details

Farr-Wharton, G., Foth, M., & Choi, J. H. (2013, Sep 9). EatChaFood: Challenging technology design to slice food waste production. In Green Food Technology: Ubicomp opportunities for reducing the environmental impacts of food, UbiComp Adjunct Proceedings (pp. 559-562), Zürich, Switzerland. New York, NY: ACM. http://eprints.qut.edu.au/60908/

5.3.3 Preamble

EatChaFood was the third intervention employed as part of this thesis. EatChaFood is a mobile application developed using the findings from the previous two interventions to inform its design and the features it provided. EatChaFood responded to a design challenge to improve how users can use mobile technology to increase knowledge of their food supply and location awareness, and to improve their level of food literacy. The application also provided a shared space, which explored how users may share food if the process was facilitated through technology.

Firstly, EatChaFood provided users with an inventory of their food items. This provided users with the opportunity to view a complete list of their inventory during food shopping and reduced the risk of doubling up on items. This feature also provided the opportunity for users to try food they may not otherwise have known was available for consumption. The inventory list was colour coded, incorporating the design techniques of the Colour Code Project, to encourage the use of a virtual

colour scheme for items to be placed and located. Food items were ranked according to their expiration: green, yellow, red and black were used to signify if a food item had 5 or more days, 2-4 days, less than 2 days or 0 days left until expiry. This feature was implemented to target the improvement of a user's food location knowledge.

Secondly, EatChaFood provided users with a photo of their fridge interior, similar to the photos taken by FridgeCam. The photo provided a front-on view of a user's fridge interior to provide them with a snapshot of the food available for consumption. The photos could be utilised by users to prevent the purchase of items already in storage, assisting users to know the food available in their fridge without the need to open it. The photos had similar limitations to those experienced with FridgeCam, in that visibility of items was not always sufficient, particularly with items that did not have transparent packaging or that were located behind other items. However, this feature was implemented to target the improvement of a user's food supply knowledge.

Thirdly, EatChaFood provided users with a recipe search feature that searches for recipes prioritising the items in the food inventory that would expire within the next two days. This feature provided the opportunity for users to utilise food that may have otherwise been forgotten and subsequently expired. The recipe also provides the opportunity for users to learn how to utilise food in different ways with different cooking techniques. Therefore, this feature was implemented to target the improvement of a user's level of food literacy.

Finally, EatChaFood provided users with a shared space feature named FridgeScope, which provided users with a mechanism to share food they felt would otherwise be wasted. Users had the opportunity to select the food they wanted, which had been shared by others, and ask for the food to be sent to them. FridgeScope also provided the opportunity for users to view the fridge interior of other users. This feature was implemented to investigate how technology may assist with food sharing.

The publication noted in this section describes the development of the EatChaFood application, the features it provides and the design challenge it responds to.

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Statement of Contribution of Co-Authors for Thesis by Published Paper

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The authors listed below have certified* that:

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2. they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
3. there are no other authors of the publication according to these criteria;
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5. they agree to the use of the publication in the student's thesis and its publication on the QUT ePrints database consistent with any limitations set by publisher requirements.

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Publication title and date of publication or status:
EatChaFood: challenging technology design to slice food waste production, 2013

Contributor	Statement of contribution*
Geremy Farr-Wharton	Wrote manuscript, developed experimental design, conducted experiment and data analysis, developed tools used to collect data.
26/11/2013	
Marcus Foth	Contributed to manuscript, aided experimental design
Jaz Choi	Contributed to manuscript, aided experimental design

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

MARCUS FOTH — Name
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07/11/2014 — Date

EatChaFood: Challenging Technology Design to Slice Food Waste Production

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http://dx.doi.org/10.1145/2494091.2497311

Abstract
This paper presents work in progress of *EatChaFood* – a prototype app designed to increase user knowledge of the currently available domestic supply and location of food, with a view to reducing expired household food waste. In order to reap the benefits that EatChaFood can provide we explore ways to overcome manual data entry as a barrier to use. Our user study has to recognise the limitations of the prototype app, and conduct an evaluation of the interaction design built into the app to promote behaviour change. Innovations in the near future such as the automatic scanning of barcodes on food items or photo-recognition will close the gap between perceived prototype usability and usefulness.

Author Keywords
Food, food waste, human-computer interaction, urban informatics, behaviour change, interaction design.

ACM Classification Keywords
Human-centered computing → Empirical studies in HCI; Empirical studies in interaction design

General Terms
Human Factors; Design

Figure 1. An example of the main screen a user will see.

Introduction

People in industrialised societies are throwing away approximately 25% of edible food each year [8], with food waste being produced along the entire food supply chain. Ambler-Edwards et al. [1] argue that a significant portion of losses occur in domestic households. This waste is often deposited in landfills. Landfill on average contribute 8% of global annual greenhouse gas emissions [10]. Household food waste is characterised in four specific forms: original food, partly consumed/used food, leftovers (plate waste), and preparation residues [8]. Within the household, food waste production can be attributed to a combination of lifestyle choice and an amalgamation of incorrect knowledge about food itself. This combination of factors promotes behaviours that can lead people to produce food waste in the home.

Further, food is a relatively cheap commodity (in comparison to clean drinking water or electricity) in industrialised countries. This often encourages apathetic purchasing habits and does not necessarily consider implications of wasting purchased food. If food items expire before they can be consumed (i.e. reaches the recommended 'best before' date), they can just as easily be replaced during the next grocery shop. However, this often depends on the product, e.g., condiments may be held onto long passed expiration. Reflecting on this practice, the majority of household food wastages occur because of behaviours present during the purchasing and storage of food. Therefore, design interventions targeting behaviours at these phases may stimulate a reduction in expired household food waste.

Recently, human-computer interaction has been noted to be in a favourable position to assist in a behavioural change process, regarding environmental sustainability [4]. This presents an opportunity to use technology that builds on HCI concepts to facilitate a shift towards behaviours that reduce expired household food waste. The key elements that must be considered when designing technology to stimulate behaviour and attitude change include leveraging both engagement and interaction [c.f. 3]. Further, Bishop [2] argues that maintaining a new behaviour over time is a difficult challenge. While there have been many studies that have investigated how HCI concepts embedded in technology can be used to change behaviour (e.g.[7]), the majority have not been able to sustain new behaviours. We are interested in design interventions that both change existing as well as sustain new behaviours. However, different strategies may be necessary for each phase.

EatChaFood App

EatChaFood is a mobile app designed to encourage users to eat their food prior to expiration. It forms part of a three-year program of design research looking into ways how best to respond to user behaviours that lead to household food waste. The research has identified three key contributing factors of expired food waste in households:

1. Food supply knowledge: Does a person know what food items are available in their fridge and pantry?
2. Food item location knowledge: Does a person know the location of food items available in their fridge and pantry?
3. Food literacy [9], referring to the acquired knowledge and past experiences of a person in

relation to, among other dimensions, food selection, preparation, and consumption, as well as food lifecycles.

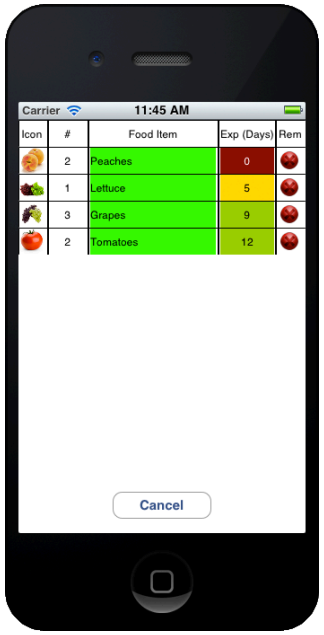

Figure 2. An example of food items belonging to a colour.

EatChaFood is the third design intervention of the research program, and seeks to address all three identified factors. It does this by implementing some of the successful characteristics identified in the previous two interventions [5, 6]. The intention of EatChaFood is not to directly reduce household food waste; rather, by impacting the above factors and informing users of their shopping and storage practices, we hope to achieve a reduction in expired food waste. A similar approach was used with the previous two interventions, both contributing to a reduction in expired food waste of varying degrees.

EatChaFood provides a single account for all members of a household, and household data is stored online. Upon logging in, users are provided with an initial view of the interior of the household refrigerator. The photo is taken regularly by a camera installed within the household fridge [6] (e.g. Figure 3). Overlaid on this photo is a colour configuration specific to the household's fridge. The colour configuration is editable by any household member. Each colour represents a food type (e.g., green refers to fresh produce) and the location where a user will find a food item. Sliders enable users to increase or decrease the transparency of the overlay, enabling the user to view items in their fridge interior without obstruction. Figure 1 shows the interface of the main screen.

As food expires, the relevant section of the overlay would flash to alert the user. Upon selecting that section, the user is taken to a list of products for the corresponding food type. Figure 2 provides an example of this. The user is given the option to view a full list of their inventory ordered by food type.

Either option provides users with more details about each product with items ranked by expiry date (if available). Users can delete items when they are consumed and are also able to find a recipe that incorporates the items. Both the visual representation and detailed list of food stocks increase a user's knowledge of their currently available food supply. Furthermore, the colour-coded representation of item locations increases a user's awareness of where they can locate food items. The recipe system assists users in learning new ways to use their food before it expires. The expiry system provides users with assistance to i) know how long food should last when refrigerated and ii) to use their senses when determining if food is edible if it has passed expiration.

Responding to Design Challenges

Australian food infrastructure does not currently allow for information about food items to be easily codified at the point of sale. In some countries, such as the U.S., certain information can be appended onto a food item using a barcode, which can link to corresponding databases which include complementary information such as the food's name, type and expiry. This limitation in the current Australian food infrastructure causes the process of adding new items into EatChaFood to be unnecessarily user-intensive. This is a challenging problem to solve because a more user-intensive process may lead to reduced engagement. Therefore, there is a greater risk that study participants will either discontinue their use of the prototype app, or find it challenging to distinguish between these usability

Figure 3. An example of a photo taken by FridgeCam.

limitations inherent in the nature of a prototype and the actual usefulness of the interaction design strategies being evaluated by the user study.

To ease the burden of manual data entry, a two step click-through process has been introduced: A user selects a food type, then the food item and quantity. Furthermore, we are currently responding to this design challenge by also exploring new ways of offering additional value and incentives to users. Extra features to be trialled that may justify the current burden of data entry include an advanced system that matches recipe suggestions to available food items as well as allows for personal recipe variations to be shared with others; communicating the availability of excess food items to friends or neighbours and publishing of fridge inventory lists or photos with other users for comparison or social purposes, such as potluck dinners. An evaluation of this process is currently being undertaken through testing the application with study participants. Two user studies, each involving five participants are currently being undertaken.

Conclusion

The EatChaFood app has been designed to facilitate a reduction in household expired food waste by increasing the awareness and knowledge of users about their stored food. We hope the implications of the findings will be valuable, building on current knowledge in interaction design and HCI with respect to both behaviour change strategies and food waste research.

Acknowledgements

We thank our study participants for their time and contribution, as well as Geraldine Fitzpatrick and Eva Ganglbauer for their feedback and advice. This research is supported under the Australian Research Council Linkage scheme (LP100100232); we thank our partners for their support: www.urbaninformatics.net/partners

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[9] Vidgen, H.A. and D. Gallegos, Food literacy: time for a new term or just another buzzword? *Journal of the Home Economics Institute of Australia 17,* 2 (2010) 2-8.

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5.4 RESEARCH ACTIVITY 6: EVALUATION OF MOBILE FOOD APPLICATIONS (PUBLICATION 6)

5.4.1 Overview

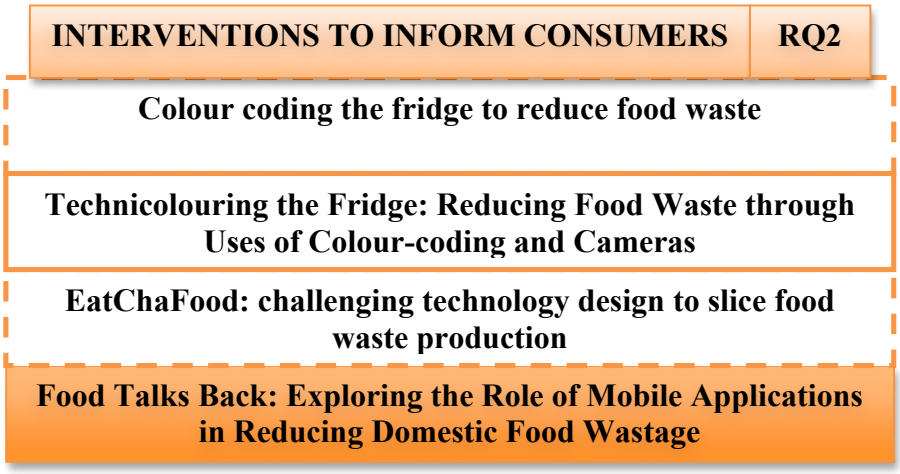

Figure - 25 Illustrates the publication described in this section of the chapter.

5.4.2 Publication Details

Farr-Wharton, G., Choi, J. H., & Foth, M. (2014, Dec 2-5). Food Talks Back: Exploring the Role of Mobile Applications in Reducing Domestic Food Wastage. In Proceedings of OZCHI 2014, Sydney, NSW. New York, NY: ACM. http://eprints.qut.edu.au/75843/

5.4.3 Preamble

The final research activity undertaken as part of this thesis to investigate RQ2 involved examining the use of two commercially available applications, Fridge Pal and LeftoverSwap, as well as the EatChaFood application developed as part of this thesis.

FridgePal provides a range of features purposed to assist users with managing their groceries and planning their next meal. The application has several defining features that enable the user to (i) create and manage shopping lists; (ii) add food items manually using a barcode scanner or from previous shopping lists; (iii) view and manage food items added to the inventory and divided into fridge, freezer and pantry storage categories, and; (iv) search recipes utilising food added to the inventory. Push notifications can be used to alert users of products close to expiry. Fridge Pal was used as part of this thesis to investigate how the app's features might help improve food supply knowledge and the level of food literacy of users.

LeftoverSwap connects those who share food with those who shared food. Users are provided with a local map, and shared items are presented as pins. Users take a photo of surplus food and provide a description before sharing the item at their current location. Users can also instant message the sharer of a food item. LeftoverSwap is used as part of this thesis to examine how food sharing can reduce food waste within a known community, as well as helping to facilitate social engagement between people.

Finally, EatChaFood encourages users to consume their food prior to expiration by providing features to assist people with managing their food, such as adding food items to an inventory, viewing all food in an inventory categorised by food types, and searching recipes containing inventory items. This app extends Fridge Pal's functionality in three ways. Firstly, it provides photos of a user's fridge interior in addition to a list of available inventory items. Secondly, it provides users with a colour code scheme to improve systematic storage within their fridge. Users customise the colours representing foods on their fridge shelving. Thirdly, a shared space named 'Fridgescope' provides users with the opportunity to share food with other users. EatChaFood also provides passive notifications of food expiry by categorising food: (i) green – 5 or more days left, (ii) yellow – 2 to 4 days left, and (iii) red – less than 2 days left. EatChaFood was used to examine the app's effectiveness in providing users with improved knowledge of what and where food items are available in storage. The app was further used to investigate how the recipe and food sharing features were utilised and if these had implications for food literacy.

These three applications are explored in the publication described in this section and were used to inform the sub-question of RQ2: *How can mobile applications help facilitate food sharing and improve consumer knowledge regarding food supply, location and literacy to promote changes towards more sustainable food practices within domestic environments?* The outcomes of this publication were the final piece required to inform the investigation of RQ2 of this thesis: *How can interventions that build on HCI be used to overcome the shortcomings of previous domestic technologies by providing users with improved food supply and location awareness to encourage changes towards sustainable food practices?*

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Food Talks Back: Exploring the Role of Ubiquitous Technologies in Reducing Domestic Food Wastage, 2014

Contributor	Statement of contribution*
Geremy Farr-Wharton	Wrote manuscript, developed experimental design, conducted experiment and data analysis, developed tools used to collect data.
26/11/2013	
Marcus Foth	Contributed to manuscript, aided experimental design
Jaz Choi	Contributed to manuscript, aided experimental design

Principal Supervisor Confirmation

I have sighted email or other correspondence from all Co-authors confirming their certifying authorship.

MARCUS FOTH — Name
Signature
07/11/2014 — Date

Food Talks Back: Exploring the Role of Mobile Applications in Reducing Domestic Food Wastage

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ABSTRACT

Mitigating domestic food waste reduces its environmental and economic impacts. In our study, we have identified the use of mobile technology to support behaviour change as a key tool to assist the process of reducing food waste. This paper reports on three mobile applications designed to reduce domestic food waste: Fridge Pal, LeftoverSwap and EatChaFood. The paper examines how each app can influence consumer knowledge of domestic food supply, location, and literacy. We discuss our findings with respect to three considerations: (i) assisting with the user's food supply and location knowledge; (ii) improving the user's food literacy; (iii) facilitating social food sharing of excess food. We present new insights for mobile interventions that encourage changes towards more sustainable behaviours to reduce food waste.

Author Keywords

Mobile, HCI, behaviour change, user behaviour, Fridge Pal, EatChaFood, LeftoverSwap, food supply, food location, food literacy, food sharing, social engagement, urban informatics, Australia

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Food waste poses a threat to environmental and food sustainability. According to Schneider (2008), 25% of the global edible food supply is wasted each year. Ambler-Edwards, Bailey et al. (2009) argue a significant portion of wastages occur within households. Subsequently, public and private institutions have developed policy, interventions and incentives to encourage consumers to reduce their domestic food waste. However, despite these activities, food wastage still comprises approx. 40% to 60% of a household's total annual garbage (Caswell, 2008), which Wade (2011) argues accounts for approx. 20% of landfill contents in developed nations. Two-thirds of these wastages are preventable (Schneider and Obersteiner, 2007). The problematic implication of food waste is the release of methane gas into the atmosphere caused from decomposing food, which is a known contributor of global warming. Wang, Odle III et al. (1997) argue landfills contribute approx. 8% of the global greenhouse gas emissions, annually. Therefore, reducing domestic food wastage will reduce the need for land estates to house exhausted landfill capacities and decrease associated ecological impacts.

One solution to food wastage is food sharing, and recent technological advancements have improved the ability to share food. For example, Ganglbauer, Fitzpatrick et al. (2014) explored the use of the FoodSharing.de platform to facilitate food sharing amongst consumers, farmers, organisations and retailers in order to reduce food waste in Austria and Germany. Their findings showed that FoodSharing.de successfully facilitated the sharing of food amongst large numbers of participating people, as evidenced in 17,000 active users sharing just under 1,800 food baskets within their online community. Their research showed that online social platforms can assist or facilitate in the process of food sharing between communities. Similarly, Grimes and Harper (2008) and Wei and Nakatsu (2012) provide further support for using technology to promote the sharing of food by bringing people together for social interaction and entertainment.

This paper examines how two commercial applications (Fridge Pal and LeftoverSwap) and our own prototype (EatChaFood) can increase consumer food supply, location and literacy knowledge. Food supply and location knowledge, as well as levels of food literacy are three identified factors contributing to household food wastage behaviours (Farr-Wharton, Choi et al., 2014, in press). Further, we examine the role of each application and how they can facilitate food sharing by evaluating the barriers that limit their effectiveness. The knowledge can be used to address shortcomings to improve the effectiveness of future interventions aimed at reducing domestic food waste. Fridge Pal was chosen because of its various features that provide users with a mechanism to assist with their household food management, including food supply and location information. LeftoverSwap was chosen because it provides a mechanism for facilitating anonymous food sharing. EatChaFood was developed to serve the dual function of assisting with household food management as well as food sharing among users, in order to examine how the combination of the two might lead to a more effective application.

By examining each application in a small sample qualitative study, we seek to understand the role that mobile applications can play in reducing domestic food

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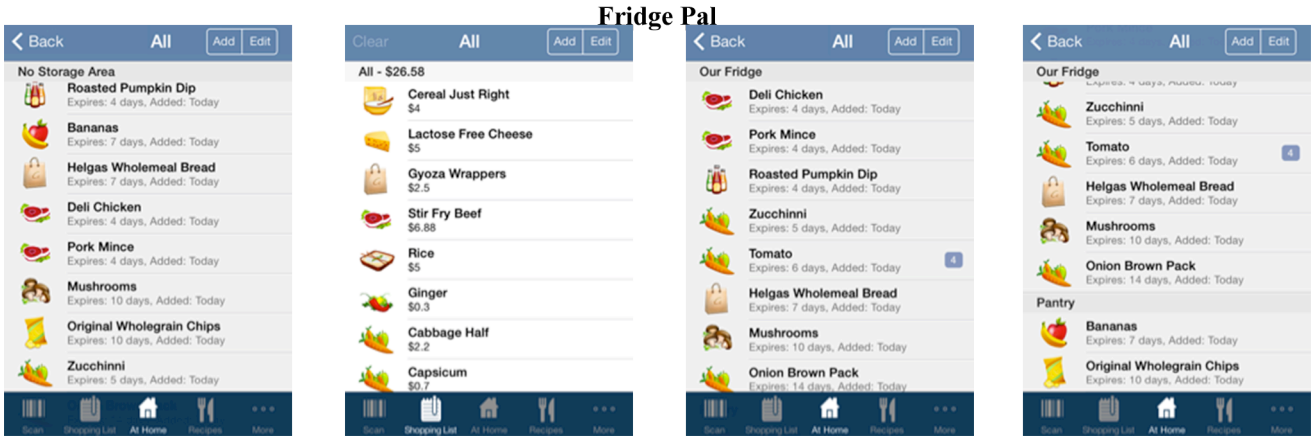

Figure 1a - d. Four Fridge Pal interfaces are presented. These are the most common interfaces users interact with.

waste by increasing consumer knowledge and facilitating food sharing.

BACKGROUND

A number of mobile applications available on the market target reduced wastage of food in various settings. Most provide features to assist individuals or businesses (e.g. restaurants) with everyday food management. The applications generally target one or a combination of the following:

- Recipe sharing and advice (e.g. Gojee[1] and Love Food Hate Waste[2]);
- Shopping list management (e.g. 222 Million Tons[3] and Green Egg Shopper[4]);
- The use of business data to inform users of cheaper foods (FoodStar[5] and Leloca[6]);
- The monitoring of business processes to reduce waste (e.g. LeanPath[7] and Wise Up On Waste[8]).

An example of an intervention targeting individual consumers includes Fridge Pal. Fridge Pal (Fig. 1a - d) provides a range of features, purposed to assist users with managing their groceries and planning their next meal. The application has several defining features that enable the user to: (i) create and manage shopping lists; (ii) add food items manually using a barcode scanner or from previous shopping lists; (iii) view and manage food items added to the inventory and divided into fridge, freezer and pantry storage categories, and; (iv) search recipes utilising food added to the inventory. Push notifications can be used to alert users of products close to expiry. We use Fridge Pal to investigate how the app's features might help improve food supply knowledge and the level of food literacy of users.

An example of an intervention promoting social food sharing is FoodSharing.de, which is a useful mechanism to reduce food waste. It operates by promoting the sharing of leftover foods that would otherwise be discarded with other individuals and communities (Ganglbauer, Fitzpatrick et al., 2014). Food sharing has been a long standing practice among existing social groups (Wei, Peiris et al., 2011). However, what remains to be explored is the likelihood of individuals sharing food with others outside of their close social circle and whether this can be facilitated by mobile applications. LeftoverSwap facilitates food sharing among known and unknown users.

LeftoverSwap (Fig. 2a and b) connects those who share food with those who take shared food. Users are provided with a local map, and shared items are presented as pins. Users take a photo of surplus food and provide a description before sharing the item at their current location. Users can also instant message the sharer of a food item. We use LeftoverSwap to examine how food sharing can reduce food waste within a known community and help to facilitate social engagement between people.

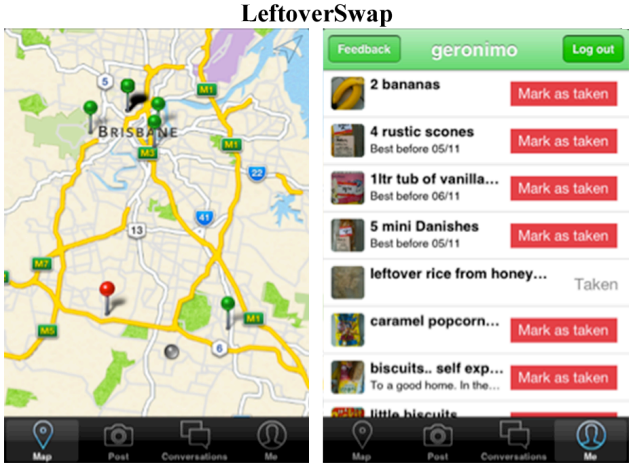

Figure 2a - b. Two LeftoverSwap interfaces are presented. These are the most common interfaces users interact with.

Using Fridge Pal in our study enables us to explore how the app influences the user's knowledge about food supply, location and literacy within their household. LeftoverSwap lets us explore food sharing within a known community. Additionally, we designed and deployed our own prototype app: EatChaFood, which

[1] https://itunes.apple.com/au/app/gojee-food-drink-recipe-app/id675249105?mt=8
[2] https://itunes.apple.com/au/app/love-food-hate-waste/id578274009?mt=8
[3] https://itunes.apple.com/au/app/222-million-tons/id528965282?mt=8
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[5] https://itunes.apple.com/au/app/food-star-capture-rate-share/id710401134?mt=8
[6] https://itunes.apple.com/au/app/leloca-instant-nearby-deals/id465271753?mt=8
[7] http://www.leanpath.com/
[8] https://play.google.com/store/apps/details?id=uk.co.torchb2b.waste

Figure 3a - d. Four EatChaFood interfaces are presented. These are the most common interfaces users interact with.

incorporates features from both apps in order to explore the effectiveness of a single application.

EatChaFood (Fig. 3a - d) encourages users to consume their food prior to expiration by providing features to assist consumers with managing their food, including: adding food items to an inventory, viewing all food in an inventory categorised by food types, and searching recipes containing inventory items (Farr-Wharton, Foth et al., 2013). This app extends Fridge Pal's functionality in three ways. Firstly, it provides photos of a user's fridge interior in addition to a list of available inventory items. Secondly, it provides users with a colour code scheme to improve systematic storage within their fridge. Users customise the colours representing foods on their fridge shelving, as described by Farr-Wharton, Foth et al. (2012). Thirdly, a shared space named 'Fridgescope' (Fig. 3c) provides users with the opportunity to share food with other users. EatChaFood also provides passive notifications of food expiry by categorising food: (i) green – 5 or more days left; (ii) yellow – 2-4 days left, and; (iii) red – less than 2 days left. We investigate the app's effectiveness in providing users with improved knowledge of what and where food items are available in storage. We further investigate how the recipe and food sharing features were utilised and if these had implications for food literacy.

PRIOR WORK

Remembering what household food is available and where it is located can be cumbersome. This is particularly the case with longer shelf-life foods, which may not be regularly used and is stored for long periods. Knowledge of the available household consumable food is referred to as food supply knowledge. Similarly, not only knowing what household food is available, but also knowing the location of food items can be equally challenging. This food location knowledge is particularly difficult in households with limited or no systematic food storage (Farr-Wharton, Choi et al., 2014, in press). Knowledge and understanding of how to use food to meet the needs of an individual refers to a person's food literacy (Vidgen and Gallegos, 2010). Further, experiences with food can vary for different people. However, when a person has previously had negative experiences with particular foods, they can be partial to consuming it in the future. This is because their initial experience with the food can provide an incorrect assessment of the value of the food in the future. This also, in part, refers to a person's food literacy (Farr-Wharton, Choi et al., 2014, in press).

There are countless mobile apps designed to assist consumers with their everyday food practices. Some are purposed to support the common activities a user undertakes during food purchasing, storage and cooking activities. Public and private investments have capitalised on opportunities to provide greater knowledge of food usage to users and how to manage it within domestic settings, for example, by using recipe and food diary applications (Ene, 2008; Schneider, 2008). Recent design interventions have targeted raising awareness of food waste within communities, such as the Food Waste Diary and Love Food Hate Waste apps. Changing practices around food and its waste can be difficult. Using technology is only one of many possible ways to facilitate reducing domestic food waste, but an effective one. For example, Lim, Dolech et al. (2014) explored a recipe finder embedded within an app and how it helped a community of consumers find new uses for food that would otherwise be discarded. Their approach prevents food from being wasted in two ways: (i) by providing information of food usage, increasing the level of food literacy, and; (ii) prompting food consumption before expiry. Their findings indicated that technology can simulate communal meal consumption between two or more people, presenting an opportunity to bring together otherwise separate people through technology. Further, Rouillard (2012) investigated how co-locating a mobile device with the household fridge can reduce food waste. In the study, a mobile device was fastened to the fridge for the user to interact with while exploring for food. The technology encouraged the consumption of near-expiry food to reduce waste. Their findings showed the co-location of a mobile device could be used to facilitate such a process. They propose several useful technologies that could be embedded with an intervention to assist with designing similar applications. These included: voice, keyboard, camera, barcode scanner, and image recognition to manage data. These are example

#	Sex	Age	More than 1 App	Living and Working Arrangements
Fridge Pal				
F1	M	29	No	Shared household, PhD Student (Full-Time)
F2	M	30	No	Shared household, Lecturer (Full-Time)
F3	F	19	No	Family Household (parents and siblings), University Student (Full-Time)
F4	M	38	Yes (EatChaFood)	Family Household (partner and child), Stay At Home Parent (Full-Time)
EatChaFood				
E1	M	22	Yes (LeftoverSwap)	Shared Household, Masters Student (Full-Time)
E2	M	28	Yes (LeftoverSwap)	Shared Household, PhD Student (Full-Time)
E3	M	38	Yes (Fridge Pal)	Family Household (partner and child), Stay At Home Parent (Full-Time)
E4	M	28	No	Family Household (partner and two children), Entrepreneur (Full-Time)
LeftoverSwap				
L1	M	22	Yes (EatChaFood)	Shared household, Masters Student (Full-Time)
L2	M	29	No	Shared household, PhD Student (Full-Time)
L3	M	34	No	Shared household, PhD Student (Full-Time)
L4	M	29	No	Shared household, PhD Student (Full-Time)
L5	M	28	Yes (EatChaFood)	Shared household, PhD Student (Full-Time)
L6	M	30	No	Couple Household, Lecturer (Full-Time)
L7	F	35	No	Family Household, PhD Student (Full-Time)

Table 1. Presents the relevant details of participants who used each of the three applications.

interventions leveraging HCI to target food sharing and food management. However, these interventions do not directly target food supply, location and literacy knowledge, which have been identified to be key factors leading to domestic food waste (Farr-Wharton, Choi et al., 2014, in press).

Therefore, our study is guided by this research question: how can mobile applications help facilitate food sharing and improve consumer knowledge regarding food supply, location and literacy to promote changes towards more sustainable food practices within domestic environments?

METHODOLOGY

We addressed our study's research question by observing the use of each application over three-week periods. Our data collection also consisted of interviews conducted with participants at the conclusion of each observation period. Participants were recruited from respondents to a Facebook and email advert and were screened in consideration of their age, sex, living and working arrangements, and household type. Nielsen and Molich (1990) suggest that for design evaluations smaller sample sizes of between 3 and 5 participants are more effective in providing useful design evaluations than larger groups. The role of the participants was not specifically to evaluate the design of each application, which differs from Nielsen and Molich's (1990) definition of design evaluators. Rather, it was the role of participants to evaluate the use and interactions with the app, which included an evaluation of design. However, because of our study's similarity to Nielsen and Molich's (1990) definition of design evaluators, we thought it appropriate to apply their participant sample size restrictions. Subsequently, we chose to limit our sample sizes to their approximate recommended numbers: (i) 4 Fridge Pal; (ii) 7 LeftoverSwap, and; (iii) 4 EatChaFood participants. Three participants used more than one of these applications. Participant attrition was quite high in our study, particularly among females and hence, participants consisted predominately of males. We were unable to determine why attrition rates were higher amongst females than males. During each observation period, we gauged participants' use of the application of their choice once a week by questioning their thoughts regarding the application's useability and usefulness. On conclusion of each period, we asked participants a series of open-ended questions regarding four facets: (i) how the app influenced their daily practices around food; (ii) the impact the app had in reducing food waste, including informing food supply, location and literacy; (iii) usability and usefulness of the app; (iv) the impact the app had on participants' lifestyles. Thematical analysis was applied in order to evaluate the interview data and derive key themes. In addition, the interview data was cross-examined with the observations of use and interactions participants had with the applications to corroborate what was said. Table 1 presents our participants' key details.

Fridge Pal participants were asked to utilise the app's full functionality and we provided $10 iTunes gift cards to purchase the full version of Fridge Pal. This was a necessary step, because the full version allows for an unlimited number of items to be entered into the inventory and access to additional functionalities whereas the free version is limited to only three food items.

We invited colleagues from our research lab to share food through LeftoverSwap. All lab members were acquainted with one another and consisted of a total of 17 colleagues, of which, 7 people actively shared or took food. We provided a 'shared shelf' within the lab's communal fridge and accessible by participants.

LeftoverSwap was used to notify others that food had been shared. We also provided an A4 sheet of paper and a pen on the front of the fridge for participants to place their name and the item they were either sharing or taking. This was because LeftoverSwap does not make clear who takes the food items offered. We used the information provided on the piece of paper to observe the sharing of food between participants. We asked participants to place shared items on the provided fridge shelf. Participants could engage in communication with the food sharer via LeftoverSwap's instant messaging feature to learn further details of the shared food item. We sent daily emails to participants, which indicated new available food items and older items still available. We moderated the shared shelf daily ensuring expired items were removed. A series of open-ended questions differing from the other observation periods were asked of those who actively participated in the LeftoverSwap exercise. Questions related to three facets: (i) Food sharing in general regarding the circumstances that participants would either share or take food; (ii) Mechanisms that supported food sharing, such as LeftoverSwap; (iii) Future mechanisms and requirements to support food sharing.

Studying EatChaFood, we instructed participants in the use of, the app including: use and maintenance of the colour code scheme, taking fridge interior photos, adding and removing food inventory items, finding recipes, and use of the shared space, Fridgescope. We provided support to participants when necessary. We asked an additional question to the standard open-ended questions regarding how participants used Fridgescope and what they thought about food sharing.

FINDINGS

Our results are structured into themes derived from a culmination of each observation period and final interviews with participants. Three main themes emerged: (i) The applications' design and features; (ii) supporting knowledge of food supply, location and literacy, and; (iii) response to food sharing.

The Applications: Their Designs and Implications

Comments about the designs and implications of each application were continually made during participant interviews. In the cases of Fridge Pal and EatChaFood, data entry was the main issue. Almost all participants suggested the current method of data entry, a three-step process outlined by Farr-Wharton, Foth et al. (2013), would limit their continued use of the application after the study's conclusion. However, some favoured certain data entry methods. F2 stated their excitement to use the barcode scanner on Fridge Pal, but reported losing enthusiasm after some products were not recognised. F1 also wanted some level of manual manipulation of data before items were entered. F1 and F2 suggested automatic food expiry was an issue and did not provide accurate information. F2 gave the example of goat's cheese and that once opened, can expire quickly. Fridge Pal does not allow manual changes to expiration dates regardless of circumstances and in that case indicated the goat's cheese would expire in over 100 days. Also, F1 stated data editing, such as removing an item from their app's inventory was not a natural action. They explained *"when I'm in the kitchen and have just removed something from my fridge, I don't naturally think to remove it from the application. Then I get automatic notifications for something I have already eaten"* (F1). All participants raised the need to improve how data is manipulated for future iterations of the applications.

Several participants provided opportunities to improve the functionality of each application. F1, F4, E3 and E4 suggested a method of automatically populating the application's inventory with items scanned from a shopping receipt. Further, F1 indicated their preference to undertake the majority of interaction with the application through a device embedded within, for example, the refrigerator and use a mobile application for interaction during grocery shopping. F1 suggested this might reduce the burden of data removal from the application's inventory, because it would allow users to easily see what food is available within the fridge before opening the door. Another finding was identified that indicated a need to address how application notifications were delivered to users. F1 and F4 stated the usefulness of receiving push notifications as reminders to consume some food items, whereas F2 and F3 ignored or disabled push notifications, because they found them to be invasive.

Participants' responses also indicated a need for integration of the main features of their application and other tools they already use in their everyday lives, such as email for notifications. Additionally, F1 suggested a number of applications that provide nutritional information. They suggested if this information could be integrated with the food that is being added to the inventory, *"all of a sudden, you know what I'm buying and you know what I'm eating, therefore you may be able to give me some feedback on whether what I'm eating is actually good for me or not"* (F1). E2 further stated that they are already using a variety of mobile applications to serve different specific purposes. Adding an additional application would need to provide significant benefit to their life or it becomes a burden to use. However, they suggested that if an application can be used easily in conjunction with other applications they are already using or if the application can combine the functionalities of several others, then the single application might improve in usefulness and purpose. E1 also stated that future iterations of apps similar to EatChaFood would benefit

from improved and more comprehensive notifications. They suggested notification information might include not only products that are expiring soon, but what recipes they could be used in. E1 further stated recipe information could be categorised into: quick snacks, moderate meals, and longer preparation meals to provide the user with a choice, which best represents their current situation. Several participants also suggested LeftoverSwap might benefit from integration with other applications. L1, L3, L4 and L6 stated LeftoverSwap could incorporate technologies used in their everyday lives, such as email to notify users of food available in walking proximity. L1 and L5 stated the ability to customise notifications would be beneficial. They stated their preference for the ability to preselect preferred food items and be notified if other people shared those items.

Food Supply, Location, and Literacy Awareness

Our findings revealed a second theme suggesting participants felt their application supported and informed knowledge of their food supply and location, and improved their food literacy. In some instances, participants reported an increase of all three. Our findings suggested participants experienced this particularly when using Fridge Pal or EatChaFood. However, several participants indicated LeftoverSwap also contributed to increasing their food literacy. F1, F2, E3 and L2 all mentioned the applications they were using helped to improve food literacy. In the cases of Fridge Pal and EatChaFood, they did this by providing the number of days a product should remain edible under refrigerated conditions. F2 indicated this information helped to inform him of how long a product should last under normal circumstances. F2 suggested he had limited food expiration knowledge and would benefit from this type of feature in such apps. Similar comments were made by F4. Fridge Pal and EatChaFood also provided recipes utilising food that was available in the user's inventory, which participants indicated increased their food literacy in some instances. It did this by providing some participants with recipe options they may not have previously used in preparing food. F1 stated the use of Fridge Pal's recipe function helped to repurpose an item about to expire, which was bought for another planned meal. E3 indicated a similar scenario where EatChaFood helped to repurpose expiring food. Overall, all Fridge Pal and EatChaFood participants noticed a reduction in food wastage, which several participants indicated was because of an improved understanding of food expiration. Therefore, participants had experienced some level of increased food literacy.

Our findings also showed an impact on a users knowledge about their food supply. Several Fridge Pal participants suggested they would have knowledge of most of the items available for consumption in their food storage. However, F2, F3 and F4 stated they would occasionally dispose of forgotten items that had expired. Each participant suggested in some cases, those disposed items had been placed behind other newer items and eventually were forgotten about. F2 stated the notification feature of Fridge Pal was a helpful tool because it overcame the issue of items being pushed behind other newer items and allowed for consumption before expiration. F1 provided a unique view, stating the notification feature of Fridge Pal enabled a one way conversation to occur between the food and the user; *"All of a sudden food is saying 'eat me, I'm about to expire,' giving the food a voice that it did not have before"* (F1). In part, this occurrence provides food with a passive form of communication to improve its chance of consumption rather than being wasted. E3 suggested the one inventory per household function helped their household manage their food stocks effectively. However, E3 stated, *"between the inventory list and the photo of my fridge, I preferred the photo, because it showed me things like how much milk I had left."* While the photo may not have clearly shown all items, because of item placement and visibility, the visual information is often richer than the inventory list. E1 and E3 suggested having both an inventory list and a photo of the fridge interior assisted during shopping experiences. It did this by providing the users with the information they sought in both a visual and list form, such as the user inspecting if they had *"lettuce or sour cream"* (E3) in storage before purchase. E1 stated *"EatChaFood can reduce food wastage by preventing the purchase of food I already have, so the doubling up of items I have in storage does not occur."* E1 further suggested that supply information should incorporate all available storage locations, including: the household fridge, freezer, pantry and *"other sources as well, such as the fridge from work"* (E1).

EatChaFood also provided users with a mechanism to support a system of storage within their household fridge. Participants were mixed in their responses about whether they thought the colour code scheme was useful and what impact it had on food wastage. E3 stated having the system on a mobile device is not as effective as it would have been in a physical form within the fridge. The application provides the opportunity for a user to place food items according to its particular food type. E3 indicated the storage system only works if all household members actively engage with the application to remind themselves of where to place or locate items. However, E3 and E4 suggested methods to improve this would include having a physical coloured system within the fridge itself to indicate the location of food. E1 also stated an application, such as EatChaFood that provides both support for food supply and location knowledge *"helped to locate some items, but would be more useful for people who have a lot of food, such as larger family households"* (E1). Nevertheless, all EatChaFood participants favoured the colour code scheme with E2 and E3 stating the system raised their awareness of some items, particularly those items with a longer shelf life that may have been in storage for a considerably longer time than high turnover foods. Such awareness about food inventory will provide the opportunity for users to consume those items before they expire, thereby further reducing food wastage.

Response to Food Sharing

Our findings indicated a final significant theme that emerged during our analysis of EatChaFood and LeftoverSwap interviews suggesting food sharing is a controversial action for our participants. None of the

EatChaFood participants opted to take food shared by other participants. While the sample size was relatively small, we felt it necessary to explore why participants were hesitant. In questioning EatChaFood participants on this matter, all provided similar responses. The issue of trust was raised. The participants stated that unless they knew the other person, or at the very least, knew the person with a level of familiarity, they were unwilling to share food. The responses indicated a level of fear and uncertainty; in that participants did not want people they did not know potentially coming to the house to take a shared item. E3 said, *"I just don't want people knowing what I eat."* E1 and E2 indicated their concern related to the awkwardness of a stranger approaching the participant's household to retrieve the shared food item. However, several items of food were placed on EatChaFood's Fridgescope for sharing with others. E2 also stated *"the benefit of receiving free food might help motivate users to overcome the amount of data entry required to used the application."* However, this was not a general consensus amongst the other participants.

When the issue of trust was raised regarding the sharing of food, we sought to explore this further with our participants who used LeftoverSwap. We asked participants to provide us with the circumstances under which they would feel comfortable both sharing food with others and taking food shared by others. Their responses provided an indication of the circumstances, which were generally similar across all LeftoverSwap participants. Participants were more comfortable to give or take food items if the items were either: (i) packaged; (ii) shared by or to a well-known and trusted person, such as a family member or close friend, or; (iii) if a well-known and trusted person recommended the person or community where food was shared by or to. Participants' comfort reduced when sharing food amongst a known community, such as amongst work colleagues or housemates. However, participants still felt comfortable enough to consider taking or sharing items within these communities and would, in most cases, *"take the risk"* (L2, L4 and L6). This also became evident with most participants' choice to take food shared in the communal fridge. L2 stated they *"would share food to build relationships, such as sharing food at a social gathering."* Generally, participants were more willing to give food than take it. However, all participants indicated they would be hesitant to share or take food items amongst an unknown community. Again, this fell back on the issue of trust, not only in the person sharing or receiving the item, but the food item itself and the conditions it underwent before it was shared.

Our findings also showed that most LeftoverSwap participants felt a sense of responsibility for food they shared with others. L2 stated, *"I feel as though the food I share with others is a token or gesture of goodwill. If no one takes the shared food and it expires, I don't want people having negative feelings towards me because the food had expired. So I would take responsibility and remove it if it expired because no one had taken it."* Further, our observations showed the majority of LeftoverSwap participants did not share food items. However, all participants took at least one item. L2 and L7 commented on the social justice of sharing food. L2 said, *"if you share food with others, it is expected that those who take the food would at some point share food back."* L7 also provided a similar comment saying *"others should share food if they are taking it."*

DISCUSSION

Impact on Food Supply and Location Knowledge

Our study shows that there are several design features of Fridge Pal and EatChaFood that improved food supply and location knowledge for users. In the majority of cases, our findings indicated the use of the app assisted with a reduction in our participants' food wastage. In particular, an up-to-date food inventory list and a visual photo of a fridge interior were the most effective design features improving food supply knowledge. However, this process requires that all food items across all storage areas, including the fridge, freezer and pantry, be incorporated into the food inventory. A potential problem is whether it is practical to manage food through a mobile device, in a different location from where the food is stored. Our findings support the outcomes identified by Rouillard (2012) suggesting a co-located device with food storage is likely to be better in providing real-time management of food storage data. An additional functionality is required that will deliver real-time 'easy to manage' information that provides a user with their full inventory of edible foods, giving them informed choice to prepare a variety of meals. This will reduce the possibility of food items being wasted. If a full list of items were available, it would also improve recipe searches and assist users during shopping experiences. In turn, this would prevent purchases of items already in storage.

Our findings also indicated challenges in supporting food location knowledge. The findings indicate systematic storage is not a common practice amongst our participants. The virtual colour code scheme was found not to be as effective as the physical colour code scheme (Farr-Wharton, Foth et al., 2012) in reducing food waste. One explanation suggests the app requires the user to observe the colour code scheme via EatChaFood before placing food in the systematic location. We argue that this task involves an additional step that does not benefit the user. Therefore, we believe that interventions assisting food storage would benefit from being integrated with food storage. We suggest this may require a new approach to household fridge design and should be considered by fridge manufacturers in the future. We also suggest other mechanisms supporting food location knowledge – for example, radical re-thinking of the way space is utilised within food storage and using a Lazy Susan style food rotation apparatus on shelving within storage. These may improve how food storage is organised and efficiently utilise space, reducing the risk of lost or forgotten items.

The burden of manual data entry and removal was also a key issue raised by all participants involved with Fridge Pal and EatChaFood. The findings point to a need to improve how data is added and removed from the food inventory. Suggestions were made to make the process

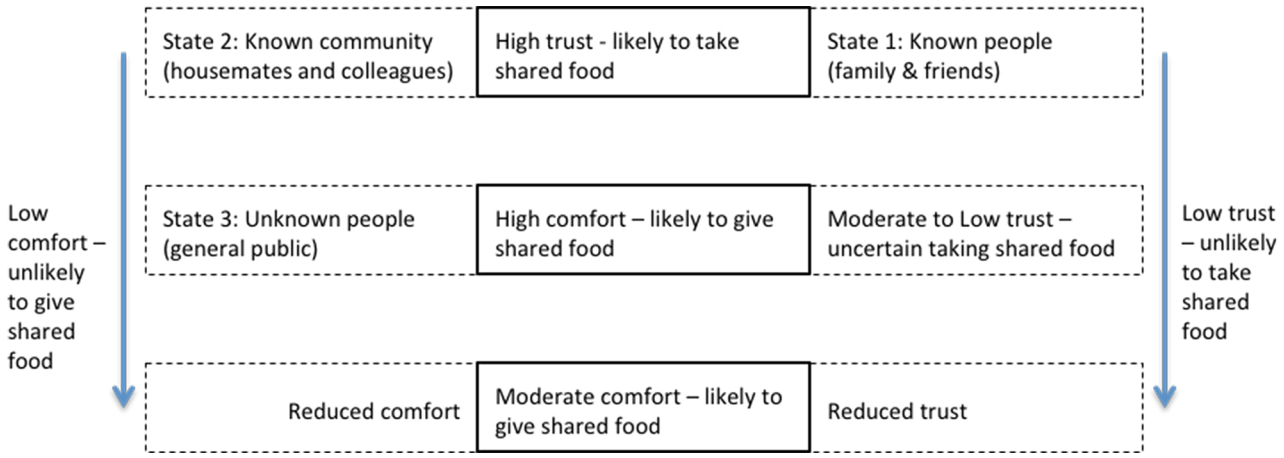

Figure 4. An illustration of our proposed food sharing acceptability scale.

automated or partly automated. This will need to be embraced by producers and retailers in the future, because there are currently opportunities that enable the capabilities to automate the process, such as scanning barcodes and including a product name and expiry. Further, other possibilities could leverage technologies, such as RFID tags that could be used to read product information as they enter or leave household storage, and then automatically update a food inventory with the product name and expiry. We recognise some limitations of these approaches. For example, Farmers Market produce might not have barcodes or RFID tags to capture details of food, such as product name and expiry. However, image recognition may play a part in the larger solution as the technology becomes more accurate and widely available amongst the general community.

Impact on Food Literacy

Each application improved a user's understanding of how to use food, thereby increasing the level of food literacy. We found that one of the more effective design features was the recipe suggestion. This feature was beneficial in informing new ways to utilise food. This was the likely contributor of a reduction in food waste, because leftover preparation residuals have an opportunity to be utilised, whereas previously, Schneider (2008) argued leftover residuals were often wasted. This process is supported by the findings of Lim, Dolech et al. (2014). However, a short-term impact is likely to be experienced in this case and we suspect previous practices will return in time, because the need for a co-located intervention has not been provided, which was indicated to be a main issue for our participants. To overcome this potential problem, engaging the user directly is necessary. However, this does not necessarily have to occur through technical interventions and instead, the intervention should aim to facilitate change in the way users view, share and source food to reduce its waste. Automatic food expiry features are also useful in informing users of food shelf life. We suggest future interventions provide automated food dating with the option to provide manual input. This would help to provide accurate information of food expiry and improve the level of food literacy for users.

We also found small improvements in food literacy because of food sharing. Not all of our participants experienced this. However, several participants indicated the use of their senses to determine if shared food was edible. This included the participant using and trusting their touch, sight and smell to determine if the food could be consumed. We argue that the communication between LeftoverSwap participants also contributed to informing a user's knowledge of food and if it can still be consumed. Our findings showed that while participants used their own senses to determine if food was edible, they also placed a level of trust in other participants they were sharing food with. This supported the participants to trust the edibility of food that was shared by other participants. We argue future interventions targeting increased food literacy amongst users would benefit from features that enable food sharing. We propose features that provide users with the capacity to communicate with other users about their experiences with food and food expiry.

Food Sharing Roles for Mobile Technology

We found the act of food sharing to be somewhat controversial for our participants. This was not the case when sharing food between family members or close friends. However, EatChaFood and LeftoverSwap participants reported hesitation and reluctance when sharing food with people outside of their immediate family and social networks. This also provides context to Lim, Dolech et al. (2014) in that sharing meals, even in virtual circumstances, may not be effective outside of one's close social circle.

We found the participants' hesitation and reluctance to share food stemmed from a concern of trust and comfort. Our findings provide insight into a food sharing acceptability scale, which depicts three states of food sharing between our participants (Fig. 4). The sharing acceptability scale is determined by a person's trust and comfort to either give or take shared food. The act of taking food is dependant on *trust*, and the act of giving food is dependant on *comfort*. We propose the first sharing state occurs with optimal trust and comfort and occurs between family and close friends. The second sharing state occurs amongst a known community, such as housemates or acquaintances and

has reduced trust and comfort with either giving or taking shared food. We found our participants were more willing to give food in this sharing state, than take it. However, some participants were willing to take shared food in this state as well. The third sharing state we propose occurs between a person and an unknown community. We found the level of trust is significantly reduced during this state and our participants were reluctant to take shared food. Similarly, we found the level of comfort was reduced in this state and our participants were uncomfortable giving food to an unknown community or person. We found this was counteracted if a trusted person became a guarantor of that community or person. Effectively, if a trusted person promotes the sharing of food amongst an unknown community, a person will be more willing to share food. We propose future interventions facilitating food sharing could integrate the lessons we have learnt in our study to strengthen their resolve. However, we learnt from Ganglbauer, Fitzpatrick et al. (2014) that food sharing can be effectively facilitated through a technological intervention. The question remains, why was food sharing effective in an unknown community with FoodSharing.de and not as successful through LeftoverSwap and EatChaFood. We postulate that the addition of a social media channel, that is, a Facebook-facilitated community page stimulated discussion around food sharing, developing a community of 'trusted' strangers (Hearn, Collie et al., 2014). LeftoverSwap does not provide a similar forum and instead, provides a food sharing approach similar to the process of 'cold calling.' We argue our work is the initial steps in understanding how food sharing may be facilitated through the use of mobile apps. Further, we confirm that technology can play a key role in food sharing facilitation in the future, particularly if these barriers can be overcome.

We also found several participants were in favour of a rating-style system that enabled users to place appeal on other users who give or take shared food items. A rating system would assist users in deciding to give or take shared food. A rating system may also serve to alleviate mistrust in taking food and provide comfort when giving food. This system can be integrated into apps, such as LeftoverSwap, which would improve food sharing facilitation. We found several participants were interested in further information about shared food, both before it was given and after it was taken. This could be facilitated by using technology and we suggest there is an opportunity to provide contextual information, such as: (i) what the conditions were that led to shared food being given, and; (ii) what happened once the shared food had been taken. We argue this information may provide further support to improve the level of food literacy among users.

Limitations

We acknowledge several limiting features associated with the mobile applications used in our study. These limitations may have influenced the choice of potential participants not to be involved in our study. For example, EatChaFood was a prototype and thus had limited features, some technical flaws, which may have caused confusion, deterring participants from using it more actively. This may have also contributed to participant attrition rates. We further acknowledge the small sample sizes of our study. We recognise the findings of Nielsen and Molich (1990), recommending smaller sample sizes for design evaluation are more effective than larger sample sizes. However, we also note that smaller sample sizes could influence the findings. We make a final note that our study examined the use of each application by predominately males, which may have influenced the findings and that the female gender is identified to be significant regarding sustainable food behaviours (Ganglbauer, Fitzpatrick et al., 2013). We do recommend this be considered when reflecting on this article's outcomes.

CONCLUSION

Our study investigated Fridge Pal, LeftoverSwap and EatChaFood and the role each play in reducing domestic food wastage. We examined each app to determine their impact on consumer knowledge of domestic food supply, location and level of food literacy and how food sharing might be facilitated through mobile technology. Our findings showed that each application has a positive impact on raising consumer awareness of their food supply, location and literacy. We also identified several challenges faced by mobile technology that facilitates food sharing amongst a community. Our findings indicated three states under which food may be shared or taken by others: (i) sharing food with known people (for example, family and friends); (ii) sharing food with a known community (for example, housemates and colleagues), and; (iii) sharing food with unknown people (for example, general public). Further, we have developed a scale to identify the level of trust and comfort a person may experience when giving or taking food. Our findings and recommendations can be applied to future design of mobile interventions targeting reduced domestic food waste.

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5.5 CHAPTER 5 SUMMARY

This chapter presented four publications that were used in conjunction to investigate and inform RQ2. The Colour Code Project was the first research activity used to begin the investigation of RQ2. The activity targeted a factor identified as part of the investigation of RQ1: current household food location knowledge and was positioned within an individual's fridge to indicate where to place and locate food items belonging to particular food types. FridgeCam was the second research activity used in the investigation of RQ2. The activity targeted another factor identified as part of the investigation of RQ1: current household food supply knowledge and was again, positioned within an individual's fridge to take regular photos of the interior. The photos were provided to users via a mobile accessible web address. EatChaFood was the third research activity, which used the findings from the previous two research activities to guide its design. The features provided through EatChaFood targeted each of the factors identified in the investigation of RQ1. EatChaFood had an additional feature, which was used to gain an initial insight into the effectiveness for technology to facilitate food sharing amongst a community of users. The final research activity examined the effectiveness of three mobile applications: Fridge Pal, LeftoverSwap and EatChaFood to reduce food waste by improving a user's food supply and location knowledge, and improve their level of food literacy, or by facilitating food sharing amongst a community of known users. The outcomes of the culmination of these research activities have informed RQ2. These research activities have presented the ways in which domestically situated interventions can play a role in helping to reduce domestic food waste by improving user awareness and facilitating the process of sharing unwanted food.

Chapter 6: Conclusion

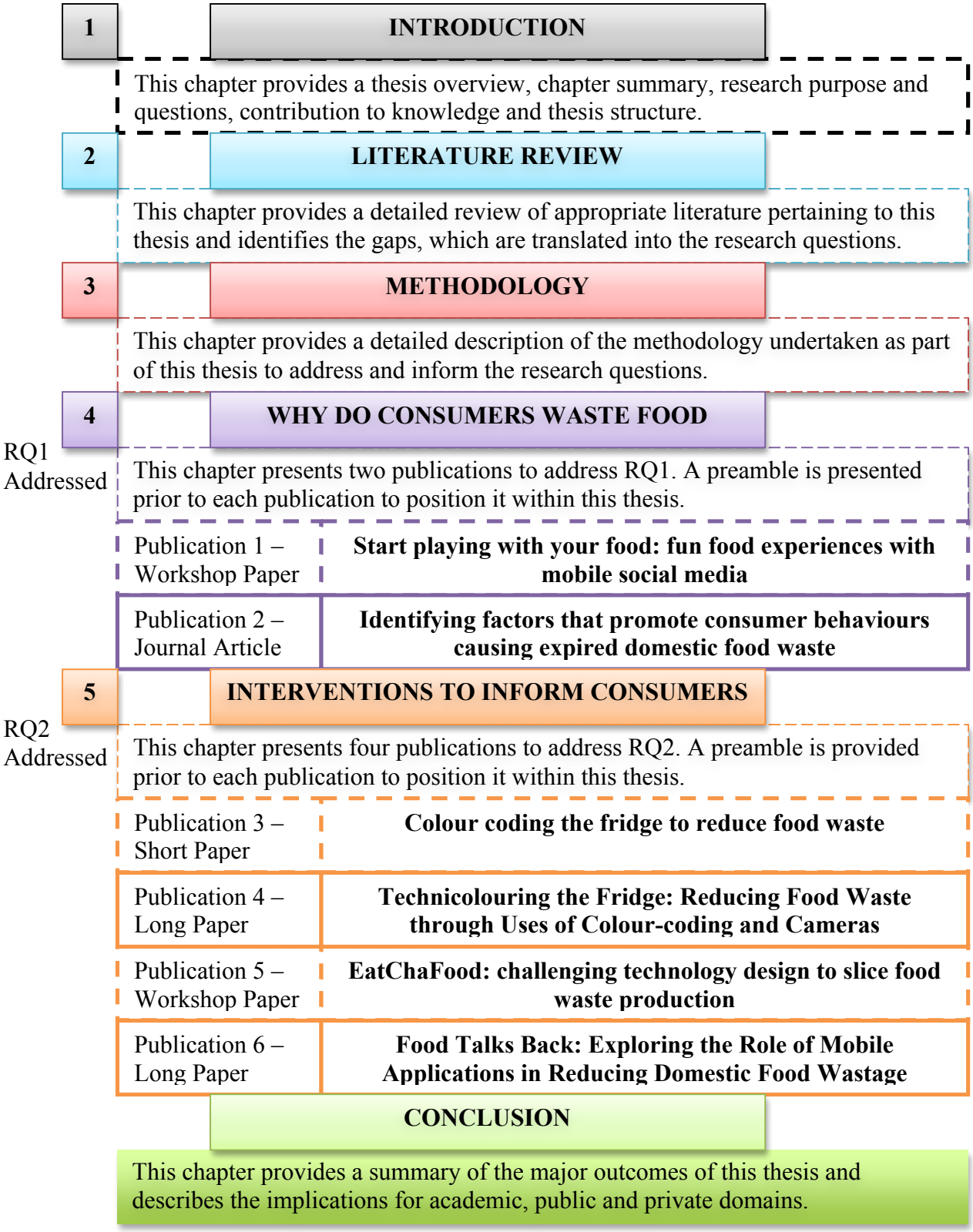

Figure - 26 A visual representation of the thesis structure with a focus on the current Chapter.

This chapter concludes this thesis by summarising the major outcomes that emerged from the research activities used in addressing RQ1 and RQ2. Following this section, the contributions of this research are detailed. Firstly, the academic contributions of this research are examined, capturing three distinct themes beginning with the implications associated with undertaking a transdisciplinary approach to identifying key factors promoting consumer behaviours resulting in domestic food waste, followed by the implications of using VBN theory to understand why people waste domestic food and lastly, the implications of using the key concepts and methods within the HCI discipline to provide useful interventions that target domestic food waste reduction. The academic contributions are followed by the pragmatic implications for improving industry and consumer food practices. In particular, the thesis has identified key design concepts that can be used in the development of new innovations targeting food storage that assist people by providing crucial information required when purchasing and storing food. Additionally, the chapter identifies how the findings in relation to changing household food storage system that enables easy and visible access to food in storage so as to reduce the risk of forgotten foods. The final contribution section details the implications for policy makers. The findings from the thesis derived new knowledge about ways of reducing consumer food wastes that could be used to inform new policies that clearly reflect the importance of working with industry to create new standards regarding the design of food storage technologies, such as the domestic fridge, in order to assist people with easily locating foods. In addition, this thesis has identified a need for policy makers to educate people of how to utilise the foods they have purchased more efficiently, so that food waste resulting from expired products is reduced.

The next section of this thesis describes the limitations of this thesis and indicates how the limitations may otherwise be improved upon in future research. The final section of this chapter describes the future research that emerges from the findings of this thesis. In this section, opportunities to extend the research are suggested. Specifically, the opportunities that could be explored to provide a greater understanding in how to reduce domestic food waste are presented.

6.1 CONTRIBUTION TO KNOWLEDGE

6.1.1 Why Do Consumers Waste Domestic Food

The first two research activities of this thesis that were described in Chapter 4: Why Do Consumers Waste Food, were used to investigate and inform RQ1: *Why do people waste food at home?* The outcomes of the activities yielded three major factors that promote consumer behaviours resulting in domestic food waste. These are:

- ***Current household food supply knowledge*** *– do people know the available food items in their storage?*
- ***Current household food item location knowledge*** *– do people know where to locate food items in their storage?*
- ***Food Literacy*** *(Vidgen & Gallegos, 2010) – referring to acquired knowledge and past experiences of people in relation to food including, for instance, trusting one's senses when determining if food is edible or not.*

Two further minor factors were linked to promoting behaviours that resulted in domestic food waste. These are:

- ***Unplanned events*** *– do people experience 'spur-of-the-moment' situations that lead to cancellation of a planned sitting to consume food previously purchased for a specific meal?*
- ***No desire to consume leftover food*** *– do people cook large meals with the intention for it to last several consecutive mealtimes, but lose desire to eat the meal after several sittings?*

6.1.2 Design Interventions to Inform Consumers

The remaining research activities of this thesis were used to investigate and inform RQ2: *How can situated design interventions encourage changes towards sustainable food practices within domestic environments?* The outcomes of the activities were that improving food supply and location knowledge and level of food literacy amongst users can help to reduce domestic food waste, and that technology can play a key role in this process. Food sharing was also identified to be a useful mechanism to reduce domestic food waste, by providing a tool to utilise leftovers

more effectively. However, the level of trust a user has for food sharers or takers is reflected in their comfort for the user to share food or take food from others.

The outcomes of the interventions also provided key features and design dimensions that can be used to guide the design of future interventions targeting the reduction of domestic food waste. Further, crucial design barriers that can detract from user interaction were also highlighted, so that future interventions can benefit from removing or reducing the impact of these barriers. Insight was also provided into the importance of positioning the interventions so as to reduce domestic food waste, especially in relation to co-located intervention embedded within typical food storage areas, such as the household fridge. These outcomes present the implications of this thesis to academia, industry, the general public, and policy makers.

The research presented in this thesis uses knowledge, concepts and frameworks from three key research disciplines: HCI, food sustainability and engagement, and consumer behaviour. The major contributions of the thesis are new and valuable knowledge for academic and industry domains within the fields of HCI, urban informatics, environmental sustainability, consumer behaviour, and food sustainability. Further, the implications of this thesis also extend to consumers and policy makers.

6.1.3 Implications for Academic Disciplines

While there have been several studies identifying the key factors that influenced purchasing behaviours (c.f. Carrigan & Attalla, 2001; Chung & Myers Jr, 1999; Green & Vergragt, 2002; Quist et al., 1998; Spangenberg & Lorek, 2002; Weatherell et al., 2003), there has been no study that has identified the significant factors that influence consumer behaviour resulting in excess domestic food waste. The outcomes of this study have identified three major and two minor factors influencing consumer behaviours resulting in excessive domestic food waste. Further, no study has identified design opportunities for domestic interventions, building on HCI, to influence consumers' food practices towards more sustainable behaviours by improving food supply, location and literacy. This study has explored several design opportunities for domestic interventions to reduce domestic food waste by improving food supply and location knowledge, and improving food literacy.

This study acknowledges the disciplinary divides and emphasises the need for a transdisciplinary approach for two reasons including: (i) the complexity of the problem; and (ii) the need to utilise values, theoretical innovations and methodological innovations that surpass discipline-specific approaches to a problem. The benefit of a transdisciplinary approach is that the expanded knowledge and practices available to form coherent concepts and ideas relevant to addressing the complex issues (Choi & Blevis, 2010; Max-Neef, 2005, p. 7) explaining consumer food behaviour. Using this approach, key models and ideas from different disciplines have been combined to form new relationships between the disciplines; together they provide an opportunity to reduce food waste in households. The theoretical outcome of this research is the identification of the significant factors influencing consumer behaviour that result in domestic food waste (particularly expired food waste). In turn, this has led to the identification of specific design opportunities for HCI to engage people by providing them with mechanisms to support knowledge and awareness about their food purchasing, storage and consumption practices. Improving the knowledge of a consumer's food purchasing, storage and consumption practices might promote the opportunity to reduce food stockpiling and might increase the visibility of otherwise forgotten foods. For the HCI research area, an evaluation of HCI and the role it can play in the process of indirectly facilitating a shift in individuals' behaviours was examined. The outcomes of the examination determined that tailored interventions that improve user awareness of their food supply, location and literacy can promote more sustainable food practices.

6.1.4 Implications for Industry

The outcomes of this thesis identify food supply and location knowledge to be important factors promoting consumer behaviours that result in domestic food waste. To support an improvement in user knowledge regarding food supply and location, industry has a key role to play. Firstly, the design of everyday appliances, such as the domestic fridge, should be a focus for industry in years to come. The domestic fridge, a central appliance used in most domestic settings, is key to assisting consumer to locate their food and know what food they have available for consumption. To do this, industry, particularly the household appliance industry, must examine how people use and interact with their appliances in order to provide mechanisms to assist them with their everyday practices. For example, if domestic

fridge designers investigate how people interact with the food within a refrigerator, they might determine the conditions under which food can be forgotten. To overcome this, fridge designers could assist people by supporting a system of food storage that increases the visibility of products available for consumption. Further, levels of food literacy can be improved amongst people by providing mechanisms that inform their understanding of how to utilise food effectively. Presenting the consumer with recipes that utilise foods that may otherwise be wasted is one such method that would promote an improvement in a consumer's level of food literacy. This thesis has indicated several interventions that could play a key role in providing people this support.

6.1.5 Implications for Consumers

New insights from this study provide consumers with mechanisms to support sustainable food practices and reduce domestic food waste. Specifically, this thesis identified that systems of food storage can be useful mechanisms to help consumers find food available for consumption in storage. In particular, we trialled the Colour Code Project and found that a system of food storage can provide users with critical information of the location of their food. The intervention used a colour code scheme to identify different food groups and to train consumers to locate similar food groups to particular locations. The outcomes were that the intervention could provide consumers with a useful mechanism to quickly and easily locate their food. Consequently the findings suggested that similar mechanisms would also be useful in helping consumers be aware of their food supply and location options.

6.1.6 Implications for Policy Makers

Food literacy was another key factor identified to promoting consumer behaviours that result in domestic food waste. This factor corresponds to the knowledge of individuals to utilise food effectively. Policy makers have an opportunity to shape consumer behaviour by putting in place mechanisms to inform consumers about how best to utilise food. This can take place in a number of ways. This thesis has noted recipe sharing and searching as an effective tool in providing useful knowledge of how to utilise particular foods effectively. This is particularly important to encourage consumers to use up partly consumed food that may be wasted, such as half an onion or avocado. Food packaging has previously been identified in the literature to be used as a mechanism that provides consumers with

information about a product. Food packaging is another tool that could be utilised by policy makers to provide targeted information about the different ways the product could be used. For example, if the consumable was to expire in its current form, the packaging may suggest another way to utilise the food, such as: (i) utilising the food as compost, or (ii) re-using some of the food's components.

A number of Australian Governmental bodies have policies designed to encourage industry and residential reduction of waste, including:

- *Local Councils, such as Brisbane City Council's Towards Zero Waste Policy – aiming to encourage recycling, diverting materials away from landfill, streamlining production and distribution systems to reduce waste production.*
- *State Governments, such as Zero Waste SA – a South Australian state government organisation aiming to encourage improved residential and industrial recycling and waste prevention.*
- *Federal Government, such as the National Waste Policy – a focus on reducing waste and focusing more on resources; and the Direct Action Plan – an initiative to reduce carbon emissions as set by the emissions reduction target and increase renewable energy in Australia.*

Brisbane City Council's (Local Government) Towards Zero Waste Policy and South Australia's Zero Waste SA (State Government) are progressive with respect to reducing waste in Australia. They are currently the only local and state initiatives that have a significant focus and plan to reduce waste in Australia, which includes food waste reduction. However, the Federal Government's National Waste Policy, while focusing on reducing waste, contradicts other initiatives at a Federal Government level, such as the need to focus on coal production as the main source of energy manufacturing in the foreseeable and long-term future. For example, the policy recognises Australia's need to become more environmentally responsible with waste and the pursuit of resources, but does not prevent or hinder actions to implement new initiatives that will have obvious and drastic repercussions for climate change and the emissions reduction target as stated in the Federal Government's Direct Action Plan. Therefore, there is a need for the Australian Government at all levels to follow Brisbane City Council's Towards Zero Waste and

South Australia's Zero Waste SA initiatives as examples and to implement policies targeting the reduction of waste that will have a positive effect on other initiatives that impact climate change.

International initiatives, such as the United Nation's Kyoto Protocol, are also general policies encouraging the countries of the world to tackle climate change. For the protocol to impact climate change on a global scale, all countries, particularly those that are developed, must implement a plan to tackle climate change that aligns itself with that of the Kyoto Protocol. However, several countries have chosen not to pursue the targets of the Kyoto Protocol, most notably the USA, because of the negative impacts it would cause to their economy. Countries that have chosen not to align their plan to tackle climate change with that of the Kyoto Protocol will have implications for the global climate. Therefore, policy debate should encourage the countries of the world to reduce their emissions through waste reduction and streamlining production and distribution systems so as to have a positive impact on the global climate.

6.2 STUDY LIMITATIONS

There are limitations associated with every body of research. It is important to describe the limitations that may have influence the claims or outcomes made as part of the research. These limitations are important to note, because they provide context to the research, which may otherwise be construed and impact upon the validity of this research.

6.2.1 Sample Sizes

Notably, the sample sizes used in each of the research activities associated with this thesis were limited. This does not translate to the inability to generalise outcomes from the findings of each research activity. Rather, it is noted in order to highlight the importance of the context of outcomes that resulted from each activity. Particularly with matters concerning design, the use of smaller sample sizes is supported by Nielsen and Molich (1990), who argue that larger samples of design evaluators can reduce the quality of outcomes. Instead, they recommend that smaller groups of approximately 3 to 5 design evaluator are optimal. Their recommendation has been noted in the research described in this thesis and has subsequently been used to limit the sample sizes of each research activity.

Conversely, the outcomes described in this thesis should not be taken in a generalisable context, because the sample sizes associated with the research activities of this thesis targeted specific demographics and types of households. Therefore, the outcomes from the observations of these samples may not necessarily reflect others outside of the contexts of which these particular samples were examined in. This does not translate to a loss of validity; rather, it can be taken in context to help understand the interactions that are likely to occur in similar settings to those examined as part of this thesis.

6.2.2 Technology Prototyping

There were limitations associated with the technology used in the later research activities. Specifically, EatChaFood was a technology prototype and there were several bugs associated with its functionality that were identified by participants after the study had begun. Implementing two other commercially available applications, Fridge Pal and LeftoverSwap, compensated for the limitations associated with EatChaFood. However, this may have affected the outcomes of the EatChaFood study.

6.3 FUTURE RESEARCH

There are obvious time and scope restrictions associated with PhD research that can be improved upon in future works. This section outlines future research directions with respect to four critical areas: (i) scope, (ii) reducing domestic food waste, (iii) encouraging sustainable food practices, and (iv) human-computer interaction.

6.3.1 Longitudinal Investigation

A number of restrictions were placed on each research activity to ensure that the scope of the activities were aligned with achievable goals that meet the standards associated with PhD research. To address the research questions appropriately and adequately, the length of time each activity ran to address the research questions was restricted. Each individual study in the research activities was undertaken between approximately three to four weeks. For example, the Colour Code Project involved a four-week observation. The first two weeks involved observations without a colour scheme applied to the domestic fridge. The remaining two weeks involved observations with the colour scheme applied. Therefore, the outcomes of the study

could not necessarily be used to provide an indication of how long the colour scheme would continue to be used in the household and whether a change in behaviour is maintained.

The length of time of the individual studies in the research activities meant that a longitudinal examination could not take place to generalise the outcomes identified. Instead, it highlights that the outcomes of this thesis must be taken in the context of how the data was gathered and analysed. The outcomes of this thesis, therefore, can be used to make an assessment about domestic practices promoting food waste behaviours and the types of interventions that may assist in reducing domestic food waste. Future research could also apply a positivist or a pragmatist approach to the research design that may serve to fill the current gaps. The objective of the research would then be to observe larger samples over extended periods of time. This would provide research outcomes that were empirical, generalizable and reliable, in the context of quantitative methods. This would also strengthen the claims made in this thesis. It also presents the opportunity to explore several key variables, such as:

- ***Measured quantities of domestic food wastage, which are divided into different food types*** *(for example, produce, dairy, meats, seafood, breads, drinks and leftovers) – this would give an indication of which foods are being wasted more than others, opening the opportunity to explore why those food types are being wasted more than others and how interventions could be more tailored to focus on reducing them over others.*
- ***Types of households that are prone to producing more domestic food waste than others*** *– this would provide a justification for tailored interventions to target specific household types. This enables the opportunity to explore why specific households produce more food waste than others and how interventions could be targeted to those specific households.*
- ***The connection between quantity of food purchased and quantity of food wasted*** *– the connection would provide a justification to target consumers during food purchasing. This would enable the opportunity to explore how interventions could be better applied to benefit consumers during food purchasing.*

6.3.2 Reducing Domestic Food Waste

The nature of PhD research places limitations regarding the scope of the study, which has implications that places restrictions on the direction that can be undertaken to achieve the associated goals of the research. The overall goal of this thesis was to target a reduction of domestic food waste. A number of interventions were implemented to determine how domestically situated interventions building on HCI could provide facilitation of food sharing and improve consumer awareness of food supply, location and literacy, towards encouraging changes towards sustainable food practices. However, these interventions have explored only a limited view of the approaches available to reduce domestic food waste. The outcomes of this thesis provide support to further explore how systems of food storage can be integrated into domestic food storage to assist consumers with improving their knowledge of the current household food supply and locations. This presents the question: *How can domestically situated interventions be integrated into household food storage to encourage a system of food storage to be practiced amongst household occupants to promote a reduction in food waste?*

6.3.3 Encouraging Sustainable Food Practices

This thesis has further highlighted the complexity and challenging nature of changing consumer behaviours. Moreover, the thesis has further observed the challenges associated with maintaining shifts in behaviour over long periods of time. This thesis targeted the factors promoting consumer behaviours to encourage shifts in food-related practices, instead of targeting behaviours directly. The interventions undertaken as part of this thesis indicated the successes of such interventions to encourage shifts in food-related practices. However, each research activity had time restrictions preventing longitudinal observations from being undertaken. Therefore, this presents an opportunity for future research to target a longitudinal study that extends on the research identified in this thesis. This would extend the outcomes of this thesis and provide further avenues for future exploration of interventions aiming to encourage sustainable food practices. A longitudinal study would also provide support for investigating the effectiveness of such interventions to maintain a shift in food-related practices over long periods of time.

6.3.4 Human-Computer Interaction

This thesis has used key concepts and methods from the HCI discipline in order to inform the design of the interventions used to address RQ2. However, lessons can be learned from the deployment of the interventions in order to draw useful knowledge for the HCI discipline to assist in the development of similar applications for use in similar purposes. For example, while the interventions used as part of this thesis were deployed to impact the factors identified in RQ1 in order to reduce food waste, the interventions themselves can be repurposed to achieve similar results in different situations and circumstances. FridgeCam is an example where this thesis has built the previous functionalities for which FridgeCam was originally designed, in order to use it to inform users about their current food supply. This presents the question: *What roles can these interventions that build on HCI to target domestic food waste reduction assume in order to provide consumers with improved knowledge in other situations and circumstances to encourage behavioural shifts?* This question has implications for HCI to assist with current passionate topics, such as energy usage reduction and fossil fuel usage discouragement.

6.4 CONCLUDING REMARKS

This chapter concludes this thesis by presenting a summary of the major findings associated with the research activities undertaken to investigate and inform the research questions of this thesis. The contributions of the thesis outcomes have been noted, particularly for academia, industry, consumers and policy makers. Its limitations have also been described, with a particular focus on the limitations regarding sample sizes and technology prototyping. Finally, the directions for future research have been noted, particularly describing the directions for longitudinal investigation, reducing domestic food waste, and encouraging sustainable food practices with possible directions for human computer interaction to reduce domestic food waste.

I have absolutely loved the research experience that my Ph.D. journey has provided me. I would like to continue the transdisplinary nature of my Ph.D. in my future research. Therefore, in my future research, I seek to utilise the insights and findings from my Ph.D. to:

a) Explore the different strategies consumers use to reduce their food waste within and external to domestic settings, and the role of social media technologies to facilitate and motivate these practices.

b) Investigate food waste in the Australian Food Industry. With just one of Australia's largest Food Grocers throwing away more than $900 million a year, I want to explore what strategies may improve the grocery shopping experience for consumers in order to improve industry efficiency of food distribution to reduce food waste.

With both directions, I seek to explore the role of ID and HCI to better inform people of their practices that are resulting in waste and to encourage more sustainable practices in order to reduce or mitigate food waste and its impact on the environment.

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